THE UNIVERSITY OF TEXAS BULLETIN
No. 3120: May 22, 1931

THE CLAYS AND THE CERAMIC INDUSTRIES OF TEXAS

By

A. D. POTTER, M. Sc.
Formerly Ceramic Engineer; Secretary of The Bureau of Industrial Chemistry 1926–1930

and

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Bureau of Industrial Chemistry

E. P. Schoch, Director

Division of the Conservation and Development of the Natural Resources of Texas

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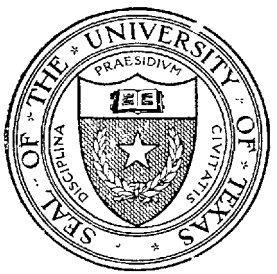

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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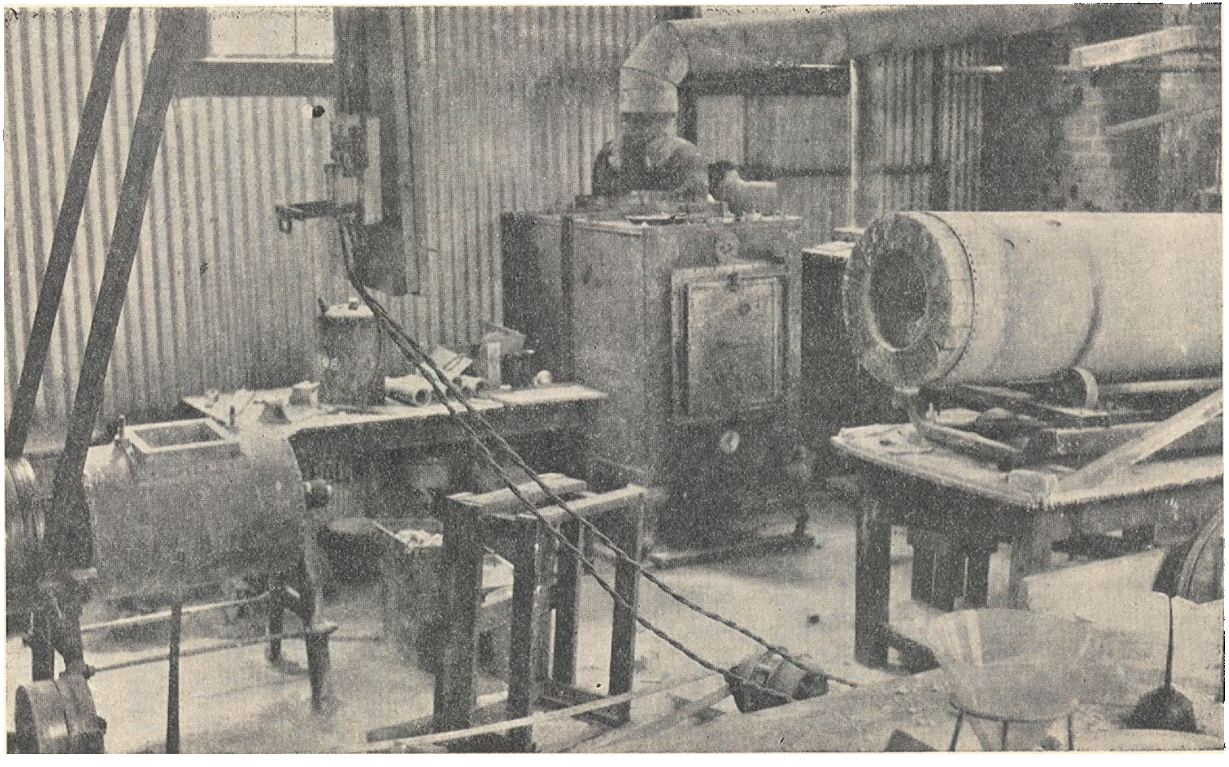

View in the Ceramic Laroratory of The University of Texas

INTRODUCTION

The first attempt to give the general public any information concerning the clay deposits which occur in this State was made in 1903. Dr. Heinrich Ries, the eminent authority on ceramic matters, who was at that time, and still is, a member of the faculty of Cornell University, was employed by The University of Texas Mineral Survey to make an investigation of the clay deposits of Texas. The results of this investigation were published in bulletin form (University Bulletin No. 102) by The University of Texas in 1908. The time and funds available did not permit Dr. Ries to make a systematic search for new deposits. Instead, his efforts were confined almost entirely to those deposits which were then known; and, as the bulk of the population was located in the eastern part of the State, the deposits investigated were confined to that area.

In the preface to the bulletin Dr. Ries states: "The accompanying report on Texas clays is based on field and laboratory work carried on during the summer of 1903 and the following winter. The former period was spent by the writer in the field examining as many of the known deposits as time permitted.

"In the limited time available it was out of the question to work out in detail the geological relations of the different clay deposits, but still in most instances the geological deposit was known, and the main point was to determine the character and possible practical value of the clays in these different formations."

No further work was done along this line until about 1919. At that time the Bureau of Industrial Chemistry installed a small kiln of the Bureau of Standards design and such other equipment as was necessary for the testing of clays. No appropriation was at that time, nor has since been, made for a systematic search for clays of economic value, and the investigations made by this bureau have been confined to the examination of such samples as have been sent in by interested parties. A large number of such samples have been examined, however, by Mr. R. A. McNees during the first few years, and by Mr. A. D. Potter during the remainder of the time that has elapsed since this equipment was installed.

All of this work has been done under the supervision of Doctor E. P. Schoch, Director of the Bureau of Industrial Chemistry. The

authors wish to acknowledge their indebtedness to Doctor Schoch for the part that he has had in this work. The ceramic investigations of the Bureau and the preparation of this bulletin have been made possible only through his interest and untiring assistance.

In 1922 Mr. Potter was sent on a one month's trip of inspection to the ceramic plants of the State for the purpose of acquainting himself with the methods in use and the nature of raw materials being worked. The time was not sufficient for him to visit all of the plants, but a number of the larger ones were studied and a considerable amount of information was collected, much of which is included in this bulletin.

Ries' bulletin proved a valuable source of reference on the subject of clays in the territory covered, but the supply of copies has long since been exhausted. Due to the fact that this bulletin was restricted in scope and has grown so far out of date, it was thought much better, rather than to reprint this old work, to write a new bulletin in which the essential information in the old bulletin could be included, together with such new information as has been collected since 1903.

Because of the large amount of new information which Mr. Potter had collected and the wide knowledge he had gained of the subject, it was felt that a report could be written which would be a worthy successor to Dr. Ries' work and a valuable contribution to the knowledge of the clay resources of Texas. Such a work was well under way when, in 1926, the Chemistry Building of the University was destroyed by fire and many of the records of the ceramic tests made by the Bureau were lost. The manuscript of the bulletin was partly saved, but in such a mutilated condition as to make it necessary practically to rewrite it. The press of various other matters since that time has delayed the finishing of the bulletin until the present time.

It is to be regretted that the new data published herewith is not more extensive. It is confined to that part of the records made prior to 1926 which could be reconstructed from the charred survivors of the fire, together with the records of the few tests made since that time. This bulletin is published now with the intention of making available to the public such information as is now possessed by this Bureau, and of acquainting the public with the fact

that the Bureau of Industrial Chemistry is interested in the clay resources of the State and is prepared to coöperate with parties who are interested in developing these resources.

In addition to the clay products industries, the Bureau is also interested in such related fields as the cement, lime, and plaster industries, and some information along these lines is included in this bulletin. All persons who are interested in the development of deposits of clay, lime, or gypsum, or in the establishment of enterprises for the manufacture of products of these materials, should communicate with the Bureau of Industrial Chemistry of The University of Texas and avail themselves of the services which this Bureau is prepared to render. A large part of the work done by this agency is performed without charge. A nominal fee of $7.50 is charged for each clay sample which is given a complete burning trial, and corresponding fees are charged for other samples on which extensive examination is necessary. No charge is made for preliminary tests or for advice or information given. In cases where a personal investigation of a deposit or plant is advisable, the Bureau will furnish the time of a trained man for this purpose, provided the interested parties will pay all traveling and other expenses attendant upon such an investigation.

This bulletin is issued for the information of all who are interested in these materials. Part One contains a brief discussion of the technology of the ceramic industries, and is intended to show what the problems in these industries are, rather than to teach anyone how to solve them. Part Two contains a recapitulation of the data previously published in Dr. Ries' bulletin, followed by tabulated results of the chemical analyses and physical tests which have been made on Texas clays and shales by the Bureau of Industrial Chemistry. The chemical analyses were made by Mr. J. E. Stullken in the laboratory of the Bureau. A few of the earlier ceramic tests were made by Mr. R. A. McNees, but by far the greatest number of them were made by Mr. A. D. Potter. There is also included a table of chemical analyses reprinted from The University of Texas Bulletin No. 1814. This bulletin contains a large number of records of analyses of Texas clays and shales, and it is thought advisable to reprint them here. Following these is a table in which is contained data from a large number of ceramic

tests made in a laboratory maintained by a number of commercial organizations in San Antonio. This information is reprinted here through the courtesy of the San Antonio Chamber of Commerce. Lastly, there will be found lists of all the various samples, recorded according to types of clay and according to counties from which the samples were obtained.

PART ONE

CHAPTER I

THE CERAMIC INDUSTRIES OF TEXAS

Clay is the most widely distributed gift of nature to man, and its products probably play a greater part in the advancement of our civilization than the products of any other material. Ceramic products have gone hand in hand with all the arts and activities of man, whereas progress in many other lines has been dependent upon the development in these products.

The term "ceramics" has been used in a limited sense to include those articles which were formed in the plastic state and then burned to produce permanency. Current usage has since broadened its meaning so that it now includes all processes which start with a raw material of an earthy nature and require treatment at a relatively high temperature before the product is ready for the market. The products which are now classed in the field of ceramics are so numerous that their manufacture includes almost one-third of the entire field of industrial activity. The following list of ceramic products will serve to indicate the magnitude of this field:

I. Structural Products.
   1. Brick.
      a. Common.
      b. Face.
      c. Paving.
   2. Hollow ware.
      a. Hollow tile.
      b. Sewer pipe.
      c. Drain tile.
      d. Conduits.
   3. Tile.
      a. Roofing tile.
      b. Floor tile.
      c. Wall tile.
   4. Decorative.
      a. Terra cotta.
      b. Glazed brick.
      c. Glazed tile.

II. Refractories.
   1. Fire clay bricks and shapes.
   2. Magnesite.
   3. Silica.
   4. Chromite.
   5. Bauxite.
   6. Diaspore.
   7. Special refractories.

III. Pottery.
   1. Tableware.
   2. Kitchen ware.
   3. Sanitary ware.
   4. Art pottery.
   5. Stoneware.
      a. Crocks, churns, etc.
      b. Chemical stoneware.
      c. Artificial stone.

IV. Glass.
1. Household.
2. Window.
3. Bottle.
4. Plate glass.
5. Colored art glass.
6. Optical glass.
7. Quartz glass.
8. Glazes.
9. Enamels.

V. Enameled metals.
1. Household.
2. Kitchen.
3. Automobile.
4. Sanitary.
5. Chemical.
6. Advertising.

VI. Abrasives.
1. Silicon carbide (carborundum).
2. Fused alumina (alundum).

VII. Insulators.
1. Electrical.
2. Thermal.

VIII. Cement.
1. Portland.
2. Natural.
3. Slag.
4. Hydraulic limes.
5. Magnesian.
6. Dental.

IX. Lime.
1. Structural.
2. Chemical.
3. Agricultural.

X. Plaster.
1. Molding.
2. Building.
3. Stucco.
4. Hard finish.

Although Texas is still largely an agricultural State, yet within recent years it has shown considerable industrial development. In 1849 her total manufacturing interests were represented by a capital investment of a little over $500,000. Today this investment is in excess of $600,000,000. Such development naturally brings with it a demand for structural materials of all kinds. In point of quantity used, lumber is still the chief construction material, but with the steadily increasing number of larger and more permanent buildings, the other structural materials, such as brick, tile, terra cotta, concrete, steel, etc., are becoming more and more important.

The manufacture of ceramic products is now one of the leading industries in the State. The United States Bureau of Census, in its report on manufacturing for 1925, lists a total of 103 ceramic plants operating in the State of Texas, the total products of which are valued at $13,382,155 per annum. This bureau has attempted to collect directly from the various concerns operating within the State statistics on their sizes and outputs at present. Responses to

questionnaires sent out to all of these plants are still incomplete, so that the figures given for 1930 are partly estimated, but these estimates can be taken as very closely representing the real figures.

Portland Cement

As might be expected, the Portland cement industry is the largest of the ceramic industries. In 1930 there were seven plants manufacturing Portland cement. Of these, only three have furnished the information requested by the questionnaire referred to above, this information indicating that these three plants have a total capitalization of $8,000,000, employ a total of 550 men, have a total daily capacity of 9,000 barrels of cement, and produce annually $8,000,000 worth of cement. The five other plants not heard from should more than double these figures, making the total capital invested in this State above $16,000,000, and the other figures correspondingly increased.

In addition to the above cement plants, there are known to be eight large plants manufacturing cement blocks, tiles, drain pipes, and other ware formed from concrete. No information as to the capacities of these plants is available.

Raw materials which are suitable for the manufacture of cement are distributed over a wide area in Texas. One of the largest deposits covers an area which averages about fifty miles in width and three hundred miles in length. It is located in the central part of the State and touches some of the largest markets. This belt enters the State in Grayson and Fannin counties, and extends southward through Dallas, Tarrant, McLennan, Travis, and intervening counties to Bexar County. In Bexar County the outcrop of the formation swings westward, but it also changes its character and becomes too calcareous for the manufacture of cement. It is not unlikely, however, that a suitable clay could be found in close proximity which could be mixed with the more calcareous material so that the belt of raw material may extend westward from Bexar County to the Rio Grande. There are a number of other areas in which suitable materials are known to occur, among which may be mentioned Tom Green, Eastland, Runnels, and El Paso counties. At Houston, cement is being manufactured from clay and oyster shells.

Clay Products

The manufacture of clay products is the next largest ceramic industry. There are sixty-eight clay-products plants listed in the United States census report of 1925. These plants are reported as follows:

Type of Plant	Number of Plants	Capital Invested	Annual Value of Product
Building brick	47	$5,033,571	$3,204,021
Tile	7	782,541	174,335
Pottery	10	162,039	71,506
Miscellaneous	4	866,458	392,090
Totals	68	$6,844,609	$3,841,952

In 1930, so far as could be determined by the investigations conducted by the bureau, there were only sixty-two such plants in actual operation, but the total output had increased immensely, illustrating the force with which the tendency toward the replacement of small plants with a fewer number of larger plants has been felt within this period of time. This tendency has seemed to be felt in the brick industry rather than in the pottery field, since there has been an increase in the number of pottery plants. The large number of abandoned brick plants substantiates this explanation of the cause of this change in number of plants. The effectiveness of the economies brought about by this consolidation into larger plants is apparent from the increase which will be noted in the ratio of value of product to capital invested.

Of the 62 clay-products plants revealed by this investigation, 43 are brick and tile plants, 17 pottery, and 2 manufacture sewer pipe and other vitrified products. Of the 43 brick and tile plants, 27 have replied to the inquiries sent out, and these replies reveal that these 27 plants have a total investment of $5,381,000, employ 1,375 men, have a capacity of 2,695,000 bricks a day, in addition to the tiles which may be produced, and have a total potential annual production valuation of $7,804,000. Among the 17 plants which have not yet replied are a number of quite large ones, so that it is safe to assume that the entire number of plants will have the same average sizes and capacities as are shown by the 27 above mentioned. Figuring the totals for all 43 on this basis, it is evident that there is in the State of Texas $8,300,000 invested in brick and

tile plants, employing in excess of 2,000 men, and producing more than 4,000,000 bricks a day, plus a considerable amount of tile, all possessing an annual value around $12,000,000.

Statistics with regard to the seventeen pottery plants are far from complete, but it is safe to assume from the information at hand that these plants represent a total investment of at least $800,000, employ over 300 men, and turn out products totaling $400,000 in annual value.

Only one of the two sewer-pipe plants has reported its statistics, but the capital investment of these two plants may be assumed to be in the neighborhood of $600,000, the total number of men employed will approximate 250, and the combined annual value of the products will be in excess of $700,000.

The information thus collected is shown in the following table, which may be compared with the table of figures reported by the United States census for 1925, which is reproduced above.

Type of Plant	Number of Plants	Capital Invested	Number of Men Employed	Annual Value of Product
Brick and tile	43	$8,300,000	2,000	$12,000,000
Pottery	17	800,000	300	400,000
Sewer pipe, etc.	2	600,000	250	700,000
Totals	62	$9,700,000	2,550	$13,100,000

The clay industry in Texas is still confined largely to the manufacture of heavy clay products; the possibilities of preparing special grades of clay and selling such prepared clay for special uses are as yet practically untried. The kaolin deposits in Real County have been shown to offer splendid possibilities for the preparation of a high-grade kaolin which could be shipped to the eastern market and sold in competition with other materials intended for the manufacture of porcelain and chinaware, but no progress has been made toward development of these deposits. The Bureau of Mines, in its publication, "Clay in 1929," by Jefferson Middleton, reports the following sales of clay in the State of Texas:

Fire clay	3,047 tons,	value $18,602
Miscellaneous clay	131 tons,	value $ 788

The above figures are probably incomplete, but suffice to show that the volume of such business is small. It is believed that, with intelligent endeavor, this volume could be considerably increased.

The clay resources of the State are quite extensive and range in quality from the common brick clays to kaolin of high purity. Clay deposits which could be developed commercially have been found in almost every county, and clay-products plants have been successfully operated in about seventy-five counties. The wide distribution of clays which are suitable for the manufacture of the more common grades of ware, such as brick and tile, is indicated by the fact that plants of this type are operated in practically every section of the State. The most extensive development of the industry, however, is in the north central part of the State. There are six plants located in Ellis County which manufacture an excellent grade of common brick of pleasing red color by the dry-press process. Practically the entire production of these plants is sold in the Dallas vicinity. There are a number of plants located to the west from Fort Worth, such as at Mineral Wells, Thurber, Millsap, and Wichita Falls. Henderson County, in northeastern Texas, produces a large quantity of clay products. There are several brick, tile, and pottery plants in Athens and in the immediate vicinity. Elgin, in Bastrop County, is the center of another important producing area in which dry-pressed face brick, tapestry brick, fire brick, and fire-clay shapes are manufactured. There is a large plant located at Saspamco, in Bexar County, which manufactures chimney linings and salt-glazed sewer pipe. Another large plant for the manufacture of sewer pipe is located at Texarkana, Texas, but obtains its clay supply from just over the State line, in Miller County, Arkansas.

Gypsum

The manufacture of gypsum products has increased considerably in the last few years. This manufacture includes both the burning of gypsum to produce the different grades of plaster, and the manufacture of this plaster into wall board, blocks, roofing, and wall tile, and moulding plaster. The major producing area for gypsum is located in the northern part of the State, plants being operated at Quanah, Sweetwater, Plasterco, and other points in that vicinity.

Another producing area in South Texas, near Falfurrias, has recently been opened up, but has not yet attained much importance. The deposits in that vicinity are plentiful and of high grade, and may be expected to assume importance in time. Other deposits, such as the one in Hudspeth County, are as yet practically untouched. The United States Bureau of Mines reports the 1924 production of gypsum in Texas to be 402,205 tons, with a value of $2,629,110. No data as to more recent production are now available.

Lime

The ceramic industry of next importance is the preparation of quick and hydrated lime. There are large lime plants located at New Braunfels, McNeil, Round Rock, Houston, and El Paso, as well as numerous small plants serving local markets. The Houston plant manufactures quick and hydrated lime by burning oyster shells. The remaining lime plants in the State utilize limestone in their kilns. The 1924 figures published by the Bureau of Mines show the lime production to amount to 60,565 tons, with a value of $570,334. The information compiled by this bureau for 1930 indicates that the large plants above named represent a total investment of around $2,000,000, employ 300 men, have a potential daily capacity of 3,000 barrels of lime, and produce a total of $800,000 worth of lime per year.

Fuller's Earth

Statistics as to the production of fuller's earth are far from complete. The Bureau of Mines reports 30,279 tons of fuller's earth, with a value of $313,782, to have been produced in the year 1924. There is known to be one privately-operated plant near San Antonio producing and marketing this material. There is another plant operated at Riverside, Walker County, by one of the major oil companies, which plant produces such quantities of fuller's earth as are necessary for this company's refining operations. Nothing is known as to the value of these products or the amount invested in these enterprises.

Possibilities for Further Development

There is still considerable possibility of establishment of new clay-products plants within the State. Some sections are well supplied with brick and tile plants, but others, particularly the more western parts, have to ship such products a long distance. It will be noted that only brick, hollow tile, sewer pipe, and pottery are being manufactured within the State. All other products, such as chinaware, porcelain, sanitary ware, roofing tile, and all the ornamental structural products, such as terra cotta, must be bought in markets outside of the State. There is therefore a long freight haul on all ware of this nature; and, since such ware has a relatively great weight in proportion to its volume, this freight cost constitutes a large part of the cost to the consumer. Sanitary and dinnerware are shipped in from the Ohio district, which is the center for the manufacture of this type of product. In view of the fact that it requires a very skilled type of labor, it would be rather difficult to establish a factory for the manufacture of this ware at this distance from the source of skilled labor supply, even though we have an abundant supply of china clay. There are many deposits in the State of clay suitable for terra cotta, glazed tile, and like products, and the manufacture of such ware presents much greater possibilities, since it does not require the skilled labor required for the other products above mentioned. Such products are at present shipped to Texas largely from Missouri, though some of them come from Georgia and New Jersey. There are no data available as to the quantity of such ware shipped into Texas, but it is evident that there is a large market for it; and if such products could be made and sold at less than the present prices, the market would very probably absorb more than it now does.

The makers of Portland cement are making a considerable effort to increase the use of cement, and there are a number of cement products which are being placed on the market as a substitute for clay products. This, of course, is competition which must be met by the clay-products industries. Both materials have their advantages, but neither can replace the other. It may be true that a concrete wall may be built more cheaply than a brick or tile wall of the same dimensions, but the demand is still greatly in favor of

face brick which is backed up by either common brick or hollow tile.

Some of the gypsum products, such as partition blocks and hollow tile, are also likely to give the clay-products industry considerable competition. These products have a decided advantage in some respects over the corresponding product in clay ware for instance, they are lighter, and their acoustical value is higher—but, on the other hand, they have not the mechanical strength that is possessed by the clay product. For this reason they are more or less limited to use in partition walls, curtain walls, or in places of similar construction where they will be required to carry very little load.

All things being considered, these three materials have very definite characteristics which fit them for certain types of construction, and there are very few large buildings erected today in which all three are not used. Cement and concrete products are necessary for foundations and the structural-form work of the building; brick, hollow tile, terra cotta, and vitrified roofing tile are necessary for the outside walls, the ornamentation, and the roofing protection of the building; while the gypsum products are necessary for inside work and as foundation for vitrified roofing tile. The fields of these three materials may overlap in some places in which the particular characteristics of the job or the desires of the purchaser will determine the material to be used, but in most instances they will have their particular field and will be supplementary rather than competitive to each other.

All of these industries need technical advice and guidance, and this Bureau, along with other agencies of the University, is prepared to give it. Many concerns have sought such help, but the number of instances of new industrial enterprises being started without any such advice is startling. The fact that a man makes a success of a commercial enterprise does not mean that he can take the lead in such an enterprise as a cement mill or a brick plant and make the same sort of success. And yet it is a common spectacle to see the board of directors of a concern, engaged in a highly technical business, composed entirely of bankers, lawyers, and merchants—all eminently successful in their fields, in all probability, but none prepared to guide the policy of such an enterprise.

Such firms may employ technical help, but the status of such help is usually about on a par with the clerical force, and the real decisions that rule the conduct of the industry are made by the non-technical directors. The fact that some such concerns succeed does not hide the fact that some fail when they could have been saved by properly trained leadership.

This state of affairs is particularly noticeable in the State of Texas. Further east, men are awaking to a realization of the fact that the engineer is the logical man to lead an engineering enterprise, but in this State we are still letting the "successful business man" tell the engineer what he is to do. The leadership of such affairs quite naturally falls to the men who have the financial ability to control the organizations, and the sons of these men have a tendency to shun the engineering professions in favor of the older professions of law and commerce, so that the technical professions are left to the poorer men, and the status remains while the generations change.

Institutions such as the University can do much toward remedying this situation by bringing to the attention of the public the advantages that are to be gained by properly training young men who are looking forward to leadership in industrial fields. By means of such education, established enterprises are supplied with new men properly equipped for leadership, but there still remains the new enterprise which is in vital need of such guidance during its beginning.

In every industry there are more conditions to be complied with than merely the established feasibility of the process. The raw materials must be obtainable in such quantities and qualities as may be necessary. The supplies, fuel, etc., must be available at low cost, as must also an adequate supply of labor. The plant location and design must be decided upon with due regard to numerous factors. Another point which frequently escapes the attention of good business men until after the more technical problems are solved is that there must be assured for the product a market which will take up the plant output at a price which will pay a profit. The ceramic industries do not have more than the average of such problems to solve, but they have their share, and they furnish a good example of the difficulties which must be met in starting new

enterprises. The brick-making industry in many instances has furnished a "horrible example" of how enterprises should not be started. The number of brick plants standing idle in the State of Texas today might lead one to believe that there is no demand for bricks, or that there is no suitable raw material available, whereas neither of these suppositions is true. Most idle plants are plants which have been started without regard to some important detail. Some plants have been built to make bricks from a clay which subsequently proved to produce an unsound product, or was so tender in its properties as to give an excessive drying or kiln loss. If proper preliminary study had been made of the properties of the clay, the plant might have been so designed as to overcome these difficulties, or it might never have been built. Other plants have operated with apparent success for a number of years, only to discover that the supply of usable clay has been exhausted before the plant has paid for itself. Such cases emphasize the necessity of a complete and accurate survey of the clay deposit before the beginning of operations. Still other small plants have been driven out of the field by inability to meet the competition of newer and larger plants whose production costs were lower. This tendency toward replacement of small local plants by a fewer number of larger plants is apt to continue to be felt. The economies to be gained by larger capacities are becoming just as evident in the clay-products industries as in many others in which small-capacity plants have ceased to exist. Because of the fact that a small brick plant can be started with a relatively small capital investment, a great many investors are entirely too ready to put their money into such a plant, but such enterprises should be discouraged. No plant should be started without ample capital to provide for sufficient production capacity to be able to meet the competition which must always be met in modern industry.

There is included in this bulletin (Chapter V) a report of an investigation of the kaolin deposits at Leakey, Texas, made by Doctor E. P. Schoch, of the Bureau of Industrial Chemistry. This is published as an example of the kind of an investigation that must be made in order to establish the value of a deposit. It will be noticed that this report covers the following points:

A survey of the deposit by a shaft and a number of drill holes to show positively the amount of material available.

Collection of a number of samples, and thorough examination of these samples to establish their composition and properties.

Study of the methods and costs of transportation from the deposit to shipping point.

Study of the methods of treatment necessary to convert the raw material into a salable product.

Investigation of the prices obtainable for the product.

In this instance the process to be employed in converting the raw material into a salable product is a very simple one, since it is contemplated merely to wash the clay and sell the purified kaolin to manufacturers of clay wares. If it is necessary to manufacture the clay into ware, the considerations involved in such an investigation are much more complex. Consideration must be given to the type of ware to which the clay is adapted; the design of the grinding, tempering, drying, and burning equipment with regard to the properties of the clay; the capacities for which the plant must be planned to give economical operation, and the market conditions which must be met in disposing of the product.

In starting a new manufacturing project, one of the first necessities is, of course, the location of a suitable deposit of clay. The usual procedure is to locate such a deposit, and then decide on the type of product to be made and the location of the plant. While this procedure is simple and frequently satisfactory, a more logical procedure is to discover a need for a certain product, and then try to locate a suitable deposit favorably located to supply this need. The abundance in which clayey materials are found makes this procedure frequently feasible. In locating such deposits, the reports of the State or United States Geological Survey will frequently be of assistance in indicating where clay may be expected. Geological reports serve only as guides to further search, since the mere fact that clay is known to be present in a certain formation, and that this formation is known to outcrop over a certain area, does not mean that a suitable clay will be found in that outcrop. Some formations will contain a good clay in one vicinity, whereas in other vicinities the same formation may be found to be so contami-

nated by sand, lime, iron, or other impurities, as to make the clay useless.

In deciding on the merits of a deposit, the first thing is to survey it completely, both its surface outcrop and its subsurface extent. Pits or drill holes should be dug to determine the thickness of the clay and the amount of overburden at various points in the deposit. Samples must then be taken of the clay. Several types of clay will usually be found, sometimes grading gradually from one type to the other, and sometimes showing a sharp boundary between the different types. In such cases the relative amounts of the different types must be observed and the difficulty with which one may be expected to be separated from the other determined. Samples must be taken of all types present.

Great care must be exercised in taking proper samples of a clay deposit. The American Ceramic Society gives the following directions for taking such samples: "A face of the body of the clay to be sampled shall be carefully stripped of loose and foreign materials, and a series of parallel trenches cut, each a straight line, so as to make as nearly as may be a vertical section entirely across the outcrop. In the case of stratified or bedded deposits which are inclined, the direction of these trenches shall be, preferably, across the dip, so that a proportionate amount of clay shall be obtained from each individual layer. Each trench shall be about 12 inches wide, and deep enough to produce about 100 pounds of material. Where natural outcrops are not available for a sampling, preliminary trials may be made with a hand auger, and test pits dug to the necessary depth to expose a section (or face) of the clay.

"As this may yield more material than is necessary for even a complete series of tests, the clay from the different trenches shall be reduced to lumps not exceeding 2 inches in diameter, mixed together and reduced by quartering to about 100 pounds, which is to be sent to the testing laboratory. The quartering shall be done on a heavy sail cloth at least 8 feet square.

"If the deposit shows distinct difference as regards structure, color, or texture, each bed showing these individual differences shall be sampled separately, provided these beds are sufficiently thick to be mined separately or can be thrown out if undesirable.

"Where the clay is stored in stock piles the sample may be taken from these, *provided they are representative.* At least one-half of the sample shall be taken from the lower third of the pile."

The samples thus collected are then given a preliminary test to determine their plasticity, drying behavior, and other general properties. If this preliminary test looks favorable, they must then be given a complete burning trial. The methods of making such trials are specified by the American Ceramic Society, so that all such trials will be made in a uniform manner. Such trials will usually show the value of the clay and the type of ware to which it is adapted, but it will not necessarily prove the feasibility of the enterprise planned. The final test of the clay should simulate actual manufacturing conditions as nearly as possible. It has been common practice in testing new deposits to ship some of the clay from these deposits to plants which are already in operation on other deposits, to make up the new clay into ware, and dry it and burn it along with the ware in the old plant. This would work, provided the old and the new clay were about the same in properties, but unfortunately this is seldom the case. Nearly every clay has its own peculiarities, and must have special treatment. The results of burning a small number of bricks made from one clay along with a large number made from another may give misleading results either favorable or unfavorable to the new clay. The best procedure is to build a small kiln to simulate the treatment to which it is planned to put the new clay, and burn the ware by itself.

The above investigations will reveal the quantity and adaptability of the clay in the deposit. The transportation facilities and the market conditions must still be studied before any conclusions are reached as to the advisability of the enterprise.

The marketing of the product is one of the largest problems with which the manufacturer of clay wares is faced. It is the only industrial problem that is strictly competitive. Difference in factory layouts, and the type of labor and machinery which is employed, will tend to produce differences in the manufacturing costs, but when these products are placed on the market they must compete with each other both in quality and cost, and each becomes the gage of the effective value of the industrial unit which has produced it.

Frequently the cost of marketing the product will equal the cost of production, and in some instances will even exceed it. In general, the common grades of clay products are of such a nature that they cannot be transported very far and still be sold at a profit. This statement applies more to the structural products and the general type known as heavy clay products, but it holds for any class of ware which is to be sold in a market where it must meet the active competition of a plant that is more advantageously located.

In making a study of market conditions, a map of the trade territory should be used, and the territory divided into concentric circles about the intended plant location as a center. The area contained within these circles should then be carefully studied to determine the quantity of ware that is being consumed or which could probably be sold during any given period of time—usually figured on the basis of one year—and the cost of delivering the product to the consumer. If the market is a competitive one, an investigation of the price of the commodity to the consumer and the amount of transportation charges will be of considerable value in determining the margin on which the plant must operate.

The transportation facilities are of great importance. The market may be sufficient to absorb a large quantity of the product, but if it is remote or if the means of reaching it are unfavorable, the transportation costs may absorb all of the possible profit.

Transportation must be considered not only from the shipping point to the market, but from the deposit or plant to the shipping point. It requires considerable capital to run a spur track, and the cost of switching on long spurs is excessive. The manufactured product must necessarily carry the interest and depreciation charges on this investment and the higher freight cost. For this reason deposits which are located more than three miles from the nearest point on a railroad are usually considered to be of no commercial value unless they are of exceptionally high grade and are suitable for very special purposes for which higher prices may be obtained. Such long-distance hauling by trucks is profitable likewise only for high-grade materials, such as is brought out in connection with the report on the Leakey kaolin in Chapter V.

The data obtained from the market survey will determine the capacity which the plant should have, and indicate the margin of profit which may be expected. A consideration of the combined facts brought out by the survey of the deposits, the examination of the samples, the study of the transportation problem, and the survey of the market will determine whether or not the plant should be built. The Bureau of Industrial Chemistry is ready and willing to assist parties interested in the development of deposits located within the State of Texas, both by advice as to methods to be pursued and by examining samples of raw materials. It is desired to encourage the establishment of new enterprises wherever the conditions warrant them, as well as to caution against heedless and unguided investment of capital in uncertain ventures.

CHAPTER II

PROPERTIES OF CLAY

I. Origin and Occurrence of Clay

Clay is the decomposition product of certain rocks and minerals. When rocks which contain alumina and silica, together with other minerals, are subjected to the weathering forces of nature they undergo certain chemical and physical changes which leave a plastic clay mass as a residue. This residue may remain in the place of its origin as a blanket covering to the parent rock or it may be washed away by the water of frequent rain storms and carried away by the flood waters to lower and sometimes distant areas where it is deposited.

Clays which remain in the place of their origin are called *residual* clays. Such residual deposits can usually be recognized without much difficulty, as they will generally show a gradual gradation from a layer of fully formed clay at the surface down through a zone of clay mixed with unchanged rock fragments increasing in size and quantity until the solid parent rock is reached. Residual clays which are derived from a calcareous parent rock are notable exceptions to this rule. These clays show a rather abrupt change from clay to solid rock. In this case the clay represents an impurity which was present in the limestone and is left behind as a residue when the limestone is converted into the soluble form by the water which filters through it.

Residual clays are not as a rule the purest type of clay deposits that are found. Owing to the nature of their origin, they will usually contain varying amounts of undecomposed rock fragments and free silica. Both of these impurities will give the clay a gritty consistency and decrease its plasticity in proportion to the quantity present. In addition, residual clays may be contaminated and discolored by mineral constituents which may have been present in the parent rock and which were not removed by the agents of weathering, or by impurities which were brought in by ground water and deposited around the clay grains. There are many residual deposits, however, which are being used with good success in the

manufacture of ceramic ware. In the manufacture of high-grade ware, such as china and porcelain, residual clays are used both in the raw and the refined states, depending upon the purity and the chemical composition of the deposit. Those residual clays which may be used in the manufacture of chinaware or porcelain are called china clays or kaolins.[1]

With the possible exception of the kaolin deposit near Leakey, Real County, there are no known deposits of residual clays in Texas. Residual clays are said to occur in the Permian, but none of these deposits have been investigated. It is not definitely known whether the kaolin deposit in Real County is of a residual or sedimentary nature. Geological facts seem to indicate that it is of sedimentary origin.

Residual clays rarely remain on slopes or in unprotected areas, but will be eroded by rain storms and washed away to lower levels, where they will be deposited in areas of quiet water. Deposits which are formed in this manner are called *sedimentary* deposits. As long as the stream maintains its velocity the clay particles will be retained in suspension, but if the velocity is retarded until the water becomes quiet, and is not disturbed by currents, these clay particles will gradually sink and form a layer of variable extent and thickness over the bottom. In this way residual clays of widely different character may be eroded and mixed by the stream and deposited together. Furthermore, the stream may drain a large area which has vastly different clays in its different sections. Since general rains are not likely to occur over the whole area at the same time, the stream will carry clays of different characters at different flood periods. These clays may all be deposited over the same area, and hence sedimentary clays present a decidedly stratified cross-section.

Horizontal variations are also of common occurrence in sedimentary deposits. The clay particles, in settling, will naturally conform to the basin in which they are deposited, and the extent of

[1]The word *Kaolin* should not be confused with *Kaolinite*. Kaolin is a general term which is applied to all high grade white-burning clays. Kaolinite is a mineral compound of definite chemical composition. It was originally thought that kaolin was composed principally of the mineral kaolinite. While kaolin generally contains some of this mineral, it has since been shown that it does not constitute the principal component.

the deposit will be governed by the area covered by comparatively quiet water. As a consequence, sedimentary deposits, except those of marine origin, will tend toward lenticular form, and the deposit may grade rather abruptly from a very fine-grained plastic clay into one of coarse texture and low plasticity.

According to their mode of origin, sedimentary clays may be divided into the following classes.

Marine Clays

This class includes those clays which have been deposited in the quiet water on the ocean floor. Since the water near the land is usually shallow and much disturbed, only the coarser materials which are brought in by the streams can be deposited near the shore line. The finer clay particles are retained in suspension until they have been carried some distance out from the land. In this way marine deposits are subjected to a greater amount of grading and the clay material which is brought in by different streams is blended together. As a consequence, marine deposits are more likely to be of a uniform character and composition than the other types of sedimentary deposits. Marine deposits will also be of greater extent and will show a gradual transition from one type to another, because the sediment from one drainage area will overlap and become mixed with that from another during the process of deposition.

With the exception of a few river and lake deposits of recent origin, the clays which are described in this report belong to this class of marine deposits.

Estuarian Clays

To this class belong those deposits which were laid down in shallow arms of the sea extending inland from the general shore line. During normal flow of the stream the clay sediment will have been subjected to a certain amount of grading, and the deposition which then takes place in the estuary will be of a fine clay-like nature, but during flood periods this grading will not be in evidence. As a consequence, estuarian clay deposits will usually show sandy laminations. Such deposits will conform to the shape of the estuary and will be limited in extent. There are many deposits of this type at present in process of formation along the Texas coast, but none of them now contain clay deposits of commercial importance.

Swamp and Lake Clays

The clays which have been formed in the basin-shaped depressions occurring along the course of the stream belong to this class. When the stream enters the swamp or lake area, the velocity of the water is checked and a deposition of a part or all of the suspended matter occurs. In such a deposit a natural gradation will be evident, since the coarser material will be deposited near the entrance of the stream into the basin, and the finer clay particles at a greater distance, where the velocity will have been reduced to a minimum and more time will have been available for the settling.

These clays will conform to the shape of the basin in which they have been deposited, and will consequently be more or less lenticular in form. The several layers may be separated by sand seams of varying thickness. The total amount of sand which may have been incorporated in the deposit may not be sufficient to materially affect the physical properties of the clay, but will make itself evident by the ease with which the individual layers may be separated from each other. Deposits which have been formed in this manner will usually be of a very plastic nature and will contain a considerable quantity of impurities.

Flood-Plain and Terrace Clays

Most of the older streams and rivers are bordered by broad plains or terraces which are of a silty nature. Often there are two or more such terraces extending like a series of steps or shelves along the sides of the valley. The lower shelf of the series may be covered by the stream during flood periods. This shelf is then known as the flood-plain. When there are several such terraces, it indicates that the stream was formerly at these higher levels, and each terrace represents a former flood-plain. During the flood period much clay sediment is deposited over the surface of the flood-plain, but owing to the fact that there is usually some current over the surface of the plain, the finer sediment cannot settle out except in protected areas. Terrace deposits will therefore be of a sandy or silty character, with pockets here and there of fine plastic material.

The character of the sediment that is carried by the stream during one period of its history and at the time that one terrace is formed may be quite different from that which is carried at another period

or during the formation of a second terrace. The clays that are present in the different terraces may therefore present a wide variation in both their physical and chemical characteristics and may be suitable for entirely different uses.

There are many deposits of the flood-plain type found in Texas. The more important ones are found along the course of the older streams, and frequently cover large areas. An example of this type of deposit is the river silt which is being used by the Butler Brick Works, at Austin, in the manufacture of common building brick.

II. Changes in Clay Deposits Subsequent to Their Deposition

Mechanical Changes

Since sedimentary deposits are formed under water and later become a part of the land surface, it is evident that some change must take place in the elevation of the deposit. In the case of flood-plain and lake deposits the change is probably due to the fact that the stream which has formed the deposit has eroded its channel to a lower level or has formed a completely new channel. As a result, the water which has been covering the deposit is drained off and the clay is exposed as a land surface. In this case no material change has been produced in the deposit except the removal of the water. The clay strata will be found in the same order in which they were deposited, and in a more or less horizontal position. Only the upper stratum will be exposed, except where gullies and ravines have been formed. These will have cut into or through the deposit and the successice strata will be exposed in their banks. The extent to which such an exposure will represent a true section of the deposit will depend upon the nature of the clay. If the upper strata are of a friable nature and disintegrate readily in water, they will slough off and cover the exposure of the lower layers. Such coverings often cause prospectors for clays to make erroneous estimates of the quantities of certain types of clays contained in deposits. If the clay is of this nature, the only means of determining the types and quantities which are present in the deposit is to study the section in fresh cuts and to drill test wells at various points and collect the cores in their proper order. If, however, the clay is of a more or less impervious nature, and does not slake readily in water, the section, as it is exposed in creek banks, may be fairly

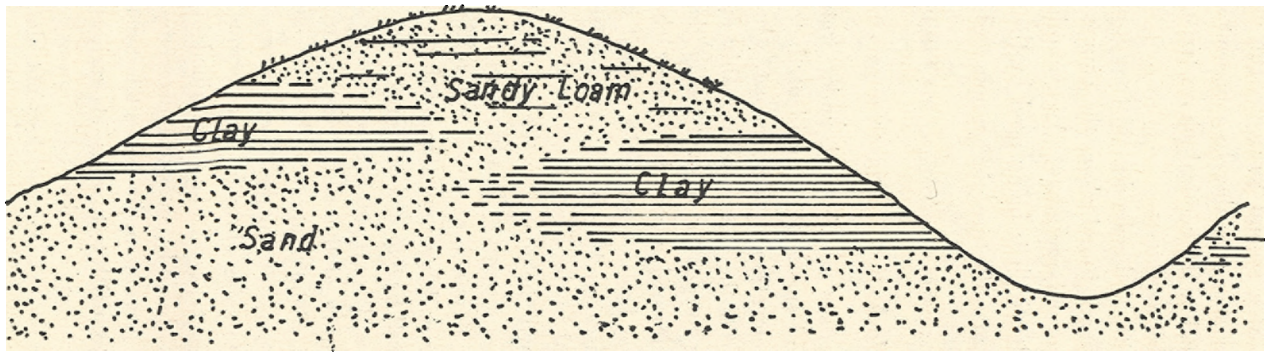

Fig. 1. Section showing Lenticular form of Clay Deposits and Illustrating how outcrops of such deposits may not represent accurately the extent of the strata

representative of the deposit. Owing to the manner in which sedimentary deposits are formed, however, a quantity estimation cannot safely be made from such an exposure. The section exposed may show a considerable depth of clay, but owing to its lenticular shape it may pinch out in a relatively short distance. (Figure 1.) Even outcrops on opposite sides of a hill do not necessarily indicate that the clay extends uniformly across from one side to the other. The only safe method of estimating the quantity of clay that is present in a deposit is to sink test wells through the deposit at a number of different points. The geological information regarding the method by which the deposit was formed and the general characteristics of the formation can be used to advantage in determining the distance these test wells should be placed from each other.

In the case of marine deposits, the exposure has been caused by a regional or local uplifting of the earth's surface. Such earth movements are not simply a vertical movement of a segment of the earth's crust but are a form of arching. This results in the segment being raised more in one place than in another. As a consequence, the strata will no longer be horizontal, but will have a slope or dip. If the surface is then eroded so that it becomes comparatively level, the individual beds will be exposed as separate outcrops. Those strata which then outcrop nearest the point or line of greatest vertical movement will be the oldest formations. When one of these beds is followed across the face of its outcrop it will be found to dip under and become covered by the other beds which were deposited over it. (Figure 2.)

An example of a regional uplift with tilting and the subsequent erosion of the exposed surface is seen in the Cretaceous and Tertiary (clay) formations of the Gulf Coastal plains of Texas. These formations were originally laid down on the ocean floor, but have since been elevated above the sea level. The elevation of the segment was not uniform, but was greatest toward the northwest. Consequently, the beds in the formation have a gentle tip toward the south or southeast. The erosion of the exposed surface which has followed has produced outcrops of the several beds, and the line of these outcrops follows a general northeast-southwest or east-west direction. The width of the outcrop depends upon the thickness of the bed and the amount of dip. Hence, we find the beds

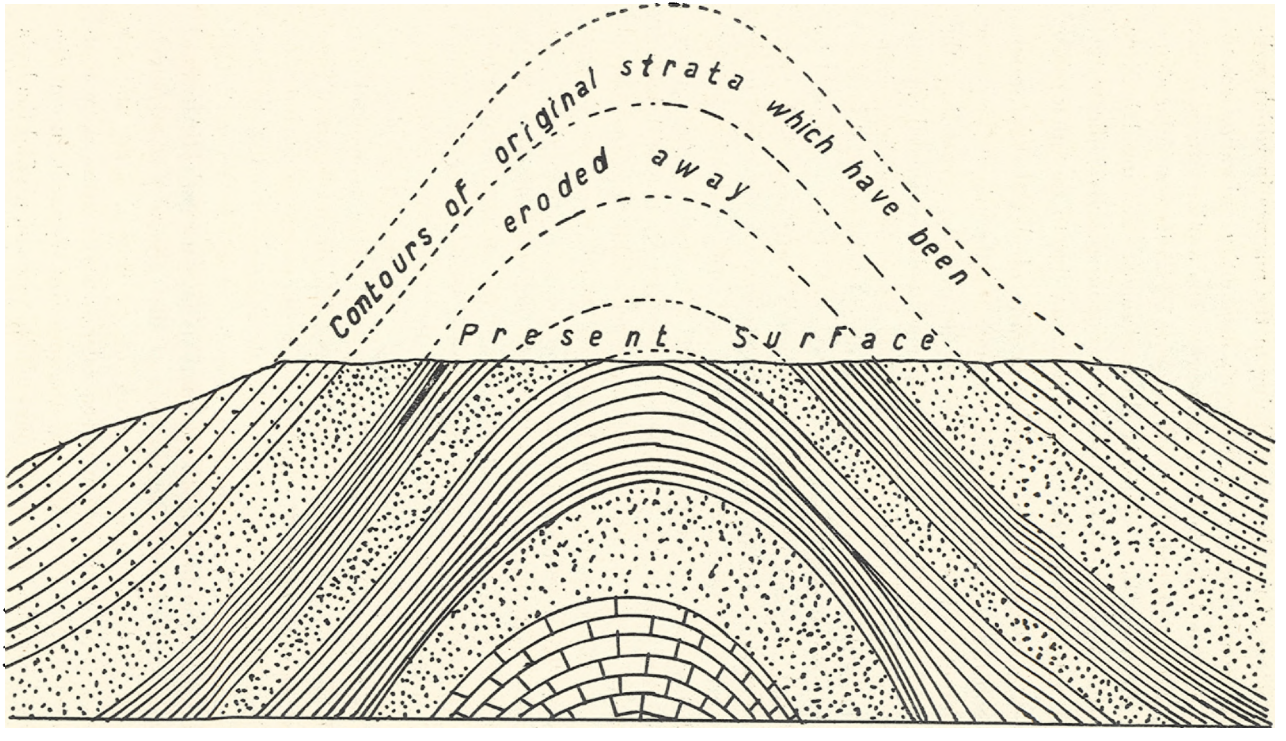

Fig. 2. Section through series of strata which have been uplifted and subsequently levelled by erosion.

of the older Cretaceous formation occurring in an irregular line across the central part of the State. As these outcrops are followed across in the direction of their dip, successively younger formations are encountered, and we find that the beds of the lower Cretaceous dip under and are covered by the younger sands, clays, and lignites of the Tertiary. Similarly, in the north central plains of the State, the clays and coals of the Pennsylvanian are found to dip toward the west and are covered by the younger red-beds of the Permian.

In addition to the uparching that raises marine clays above sea level, they may be deformed by folding or faulting. This type of deformation is of such minor importance in the more thickly populated portions of Texas that it will not be discussed here. An adequate discussion of these subjects may be found in any elementary textbook on geology.

Erosion of the surface by wind and water starts as soon as the deposit is exposed above the water level. Rain wets and softens the clay. The sun dries out the deposit and causes cracks to form. The water which seeps into these cracks and into the clay itself freezes in the winter, and by expansion breaks up and disintegrates the deposit. The wind and the surface water which drains off carry away the small grains and fragments which have been thus loosened by the weathering action.

The water that falls on the deposit does not drain off as a sheet, but is concentrated in the irregularities of the surface. This concentration of the water increases its abrasive action along the course of these irregularities, and results in the formation of gullies, valleys, and hills.

This sculpturing action of the weathering forces produces considerable change in the extent and accessibility of the deposit. For example, assume a deposit which is made up of several horizontal layers of different clays and which has been brought to the surface either by a general uplifting of a segment or by the draining off of the water which originally covered it. (Figure 3.) The subsequent erosion of the deposit for an extended period will produce changes in the topography of the surface, as shown in the figure. The upper layer has been removed over a large area, with the exception of a few small deposits capping the highest hills. The next layer is found capping the lower hills and outcropping in the

Fig. 3. Section showing how erosion may expose parallel horizontal strata.

sides of the higher hills, while the third layer is found in the beds of some of the creeks and outcropping in the sides of a few of the hills which have been eroded to the greatest depths.

Chemical Changes

The changes of a chemical nature which take place in a clay deposit are nearly all due to the process of weathering. These chemical changes may bring about: (1) a change in the color of the raw clay; (2) a change in the chemical composition by the leaching out or by the deposition of certain soluble salts; or (3) a change in the texture of the mass by (a) mellowing or softening of the clay, or (b) consolidating or cementing the clay particles into a solid rock-like mass.

The extent to which weathering may alter a deposit will depend upon the character of the deposit itself. A loose, friable clay will be attacked more readily and to a greater depth than one of a dense nature. The weathering will penetrate to a greater depth along the face of an outcrop than in parts where the clay has been covered by an overburden of other material. The amount of weathering will then depend upon the character and thickness of the overburden. Where the overburden is thin or loose the weathering will penetrate to a considerable depth, but where it is thick or of a dense or impervious nature the clay may be altered very little, if at all.

The disintegrating action of sun and rain. heat and cold, as previously described, seems to mellow and loosen the clay and increase its plasticity.

Clay outcrops which have been exposed to the weather for a considerable time will usually show tints of color varying from light buff to dark red. This color is due to the iron oxide which is present in the clay, and the depth of the color is dependent upon the amount that is present. In general, the iron oxide has been produced by the oxidation or rusting of some iron-containing mineral which was originally present in the clay. The depth to which the weathering has progressed can usually be determined by noting the depth to which this color extends. The change in color from weathered to unweathered material will not be distinct but will gradually shade from one to the other. The weathering will

usually be found to have progressed to a greater extent along joint cracks and root tracks.

All color changes that occur in clay deposits are not due solely to the process of weathering. The coloration mentioned above may not be due entirely to the oxidation of iron compounds originally present in the clay. It is frequently found that the original clay contained very little iron and that the coloration was brought in from an outside source. A neighboring stratum may be high in iron content, and the water seeping through this stratum may convert some of this iron to a soluble form and carry it into the clay deposit, where it may then be precipitated or absorbed by the clay particles.

The deposit may change more or less abruptly from a clay of light color to one of a dark color. Such changes may not be connected with the weathering, but may be caused by changes of a chemical nature brought on by other agencies. A light clay may be changed into a dark, or even a black one, by an increase in the carbonaceous matter present.

A variable amount of surface water will seep into all clays and some of it will drain off at a lower level. Such ground water always carries a small amount of carbonic acid. If the clay contains limestone, the carbonic acid will react with it to convert it to the soluble bicarbonate form. It is for this reason that clays that have been formed from a parent rock of limestone frequently contain very little or no lime. It is not uncommon to find deposits the weathered portions of which will burn to a bright red color, due to the lack of lime, while the lower unweathered portions will burn to a buff color, due to the lime that is present. Again, deposits are frequently found the unweathered portions of which will form a white scum on the surface of the ware, on drying or burning, whereas the weathered portions will not show this tendency. This scumming is due to the present of soluble salts in the clay, such as the chloride and sulphate of magnesium, calcium, etc. In the weathering of the clay these salts are leached out by the percolating waters.

Softening is the natural consequence of weathering, both through the effects of freezing and thawing, wetting and drying, and through

the removal of the soluble salts which have a tendency to cement the clay particles together.

Consolidation or hardening is the reverse of softening. In this case a soluble material is brought in by the percolating water and deposited around the clay grains, cementing them together. The cementing material is usually limonite that has been leached out of a neighboring formation. This cementation usually occurs along stratification planes and along joints or cracks in the clay. Lime is sometimes, though not often, found to have a cementing effect.

The formation of ball-like concretions in a clay deposit is also a form of consolidation. In this case the ground water carries soluble salts from some mineral, such as limonite, siderite, barite, etc., and this is deposited around some nucleus, such as a pebble or even a grain of sand. In this way concretions grow by the addition of mineral matter to the outside, and if the ball thus formed is broken, concentric rings may often be seen. They may assume almost any shape, although a ball-like form is most common. They often reach large proportions. In some clays the concretions are sufficiently abundant to be of value for their mineral content, but in most cases they are worthless, and must be separated from the clay before it can be used in a manufacturing process.

The formation of shale is another instance of consolidation, but it is not always due to chemical action. Many sedimentary clays become covered by many hundreds of feet of other sedimentary material during prolonged periods of deposition. The weight of this overlying mass will exert an enormous pressure on the lower sediments and will cause them to consolidate into a firm, rock-like mass which is known as shale. It is evident that the cohesion of the clay particles in these shales is due to pressure alone, because when the shale is ground and mixed with water it will develop as much plasticity as many of the surface clays.

In some cases the formation of shale is accompanied by chemical changes in the composition of the clay. It may be caused by the deposition of mineral cement around the clay grains, which thereby causes a general consolidation of the mass. Shales that have been formed in this way are generally very hard, and it requires a large amount of grinding and tempering to produce even moderate plasticity.

In regions where mountain-making processes have been active, the heat and pressure that have been developed have frequently transformed the shales into slates or even into mica schists. Both of these materials are devoid of any plasticity when ground.

The water covering the deposit during its formation may be teeming with animal life, and animal remains will be incorporated in the clay. The same deposit may later become a part of the land surface and be covered with vegetation. If it is then covered by new deposits, the organic matter will be converted into lignite, coal, or graphite. The pores of the clay may be filled with the distillates from the animal and vegetable remains.

III. The Mineral Content of Clays

Clay itself is not a mineral, but a complex mixture of minerals. As already mentioned, it is the decomposition product of certain rocks. Chief among the clay-forming rocks are those of the feldspar group. Orthoclase is a typical representative of this group. Its chemical composition is approximately: $K_2O \cdot Al_2O_3 \cdot 6SiO_2$. When this compound is attacked by the weathering processes it is decomposed into simpler compounds, and the process may be indicated by the following equation:

$$K_2O \cdot Al_2O_3 \cdot 6SiO_2 + 2H_2O + CO_2 = \underline{Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O} + 4SiO_2 + K_2CO_3$$

The underscored compound is the mineral kaolinite, and was originally supposed to be the basic constituent of all clays. It is now known that the mineral is present only in comparatively small proportions in most clays, and that the material known as "clay substance" is composed of a mixture of minerals bearing more or less resemblance to kaolinite in composition.

All the rocks which weather and produce clays are not pure feldspars, but are a mixture of feldspar with quartz, mica, hornblende, augite, and many other minerals. These minerals also weather and produce other minerals which will be found in the clay. During the removal of the clay from the place of its formation to the place of its deposition there may be a grading action, and the coarse, undecomposed material will be separated from the finer clay particles. Then, too, there may be a mixing of these clay particles with those from another source of a very different composition. After deposition, the clay may then be further subjected to all the

mechanical and chemical changes described in the preceding section.

All these forces tend to produce clays of a widely different character and chemical composition, and these properties will vary between wide limits. The mineral components of a clay will exert a decided effect upon both the physical character and the burning properties of the clay, but these effects are so interrelated that they cannot be predicted with any degree of certainty from the chemical analysis. One of the reasons for this is that it is almost impossible to determine the exact mineralogical composition. Two methods of chemical analysis have been used by ceramists to separate the clay into its component parts, but neither of them gives more than an approximate idea of the minerals contained.

The "Rational Analysis" is a method which endeavors to determine the mineral composition directly; i.e., the "clay substance," quartz, and feldspar are separated and determined as such by this method. It may be briefly outlined as follows:

	hot con. H_2SO_4	= soluble portion	+ insoluble portion	
Clay +	and boiling Na_2CO_3	(clay substance and mica)	(feldspathic minerals and quartz)	

The insoluble portion is then fused with Na_2CO_3 and the fused mass leached out with hot HCl. The residue from this treatment is assumed to contain all the silica in both the feldspathic minerals and the quartz. The weight of this silica subtracted from the weight of the insoluble residue from the $H_2SO_4 - Na_2CO_3$ treatment is the weight of the alkali and alumina in the feldspars, and this multiplied by 2.837 equals the feldspathic minerals. This in turn subtracted from the weight of the insoluble residue equals the weight of the quartz.

The chief difficulties in the use of this method arise from the fact that the solubilities of the different feldspars and kaolins in the strong acid varies, and the solubility of the assumed "insoluble" portion increases rapidly as the particles of this portion approach the fine state of subdivision common in clays. The method, however, when intelligently used, may give valuable information, the interpretation of the results being made with due regard to the limitations of the method.

The second method is known as the "Ultimate Chemical Analysis," and by it all of the individual basic and acidic constituents

of the clay are determined by the standard chemical methods. These are expressed in terms of the oxides of the various elements present. From the analytical data the mineralogical composition is calculated by the use of certain assumptions with regard to the distribution of the various elements. In general, more uniform results are obtained by this method than by the "rational analysis," but it is still only an approximation, due to the more or less arbitrary method of calculating the combinations. The assumptions uniformly employed for this purpose are:

$Na_2O \times 5.60 = SiO_2$ in albite (soda feldspar)
$K_2O \times 3.83 = SiO_2$ in orthoclase (potash feldspar)
$Na_2O \times 1.65 = Al_2O_3$ in albite
$K_2O \times 1.09 = Al_2O_3$ in orthoclase
Al_2O_3—total Al_2O_3 in feldspar $= Al_2O_3$ in clay substance
Al_2O_3 in clay substance $\times 1.18 = SiO_2$ in clay substance
SiO_2— (SiO_2 in clay substance + total SiO_2 in feldspar) = SiO_2 in quartz
$Na_2O \times 8.45 + K_2O \times 5.92 =$ feldspar
100%—(quartz+feldspar) = clay substance

A better knowledge of the mineralogical composition of the clay is obtained if a petrographic examination can be combined with the chemical analysis. The minerals that are present and their approximate proportions can be determined under the petrographic microscope, and with this information as a guide, the calculation from the ultimate chemical analysis can be made much more exact. In fact, this is the only method by which the mineralogical character of the clay can be determined with any degree of certainty.

The chemical analysis is of value in the study of clays of the white-ware and fire-clay types, but even then it is of secondary importance to the physical tests. The analysis will show up the impurities which are undesirable in the white-burning clays and kaolins, and from it can be calculated the alumina-silica ratio which is of importance in refractory clays. But, except in special cases, the chemical analysis is of very little importance in dealing with the more common grades of clays. It, of course, will assist in indicating the presence of those minerals which may cause trouble, such as those which will cause early fusion of the clay and short vitrification ranges. But to attempt to predict the firing behavior of the clay is to ignore the limitations of the analysis and the complexity of the chemical reactions which may take place.

The clay substance is very refractory and shows no sign of fusion until the temperature is well above 3,000 degrees Fahrenheit, but

when mixed with certain minerals it fuses at a much lower temperature. Such minerals are called "fluxes," and their action is dependent upon the amount present and the fineness of the particles. The action of these fluxing minerals is not well understood, but it is a known fact that certain mixtures will fuse at much lower temperatures than will either of the component minerals separately. It is also known that certain mixtures of definite porportions will fuse at a lower point than will mixtures of the same substances in other proportions. The melting point of pure alumina is about 2,050 degrees Centigrade, and that of pure silica is about 1,710 degrees Centigrade. By starting with pure silica and adding successively increasing amounts of alumina, mixtures of gradually lower melting points will be obtained, until finally a mixture is obtained consisting of 94.5 per cent silica and 5.5 per cent alumina which will fuse at approximately 1,545 degrees Centigrade. With still further additions of alumina the melting point again begins to rise, and continues to do so until it reaches the melting point of pure alumina—2,050 degrees Centigrade. Such a minimum fusion point is called the "eutectic point" for this pair of substances, and the mixture containing these proportions is called a "eutectic mixture." Some minerals form more than one eutectic mixture.

There are a number of minerals in the average clay which have a tendency to form eutectic mixtures. These mixtures are in turn affected by the presence of other minerals which may exert a similar tendency. It may be seen, therefore, that it is practically impossible to predict the firing behavior of a clay from the chemical analysis.

The bonding of clay ware is due to this tendency to form eutectic mixtures and the resultant fluxing action. In most ceramic mixtures there will be some portions of the mass which are present in a eutectic proportion. When the temperature becomes high enough this part will melt, and as the temperature further advances it will tend to dissolve or react with the solid portion remaining. The melted portion will collect where the angular points of the solid material are in closest contact. When the mass is cooled, this portion will solidify and cement the non-fused portion together into a hard and permanent mass.

There are three stages of fusion recognized in the burning of ceramic mixtures: first, incipent fusion, then vitrification, and, finally, complete fusion or viscosity. When a clay mixture is subjected to a rising temperature it does not change from the solid to the liquid phase immediately, as is the case with a pure compound, but softens slowly as first one and then another of the minerals present either fuses or dissolves in another fused substance. The temperature at which fusion begins and the rate at which it progresses are governed by the chemical composition of the mixture and the fineness of the aggregate. The burning behavior of a clay is not dependent solely upon either of these factors, but upon a combination of the two.

Incipient fusion begins when the first small portion of the mixture starts to melt. It may be defined as that point or stage in the burning process where the major part of the mass is still in the solid phase, but a small portion of the fluxes and of the smallest particles of the mass has fused and formed a glassy matrix which partially fills the interstitial spaces between the remaining particles of the solid phase. As the temperature advances, more and more of the mass fuses, until these interstitial spaces are nearly or quite filled by the fused portion and the mass is said to be vitrified. On still further advance in temperature the remaining solid portions fuse and the whole mass becomes a viscous, glassy mass. It is then said to be in a state of viscous fusion.

The vitrification range covers the entire period from incipient fusion to viscous fusion. For practical purposes it is desirable that this range be as long as possible. The commercial kiln in which ceramic ware is burned cannot be controlled within a short range of temperature, and if the vitrification range is short, the ware in one part of the kiln may reach such a state of fusion as to be deformed under its own weight, while that in another and cooler part of the kiln may not have reached a sufficiently high temperature to be matured. This short vitrification range is characteristic of clays that are high in lime, and for this reason vitrified ware cannot be made out of limey clays.

The term "vitrification" is rather loosely used to denote the condition to which the ware has been burned. It is said to be vitrified if a sufficient quantity of the mass has been fused to com-

pletely fill the interstitial space between the grains of the solid portion, but not so much as to weaken the ware so that it cannot carry the load required of it without being deformed. It is the point at which maximum shrinkage is attained and the mass becomes absolutely impervious. Such extreme specifications are not necessary for all commercial products, and the degree of vitrification is governed by the use for which the product is intended. The vitrified ware of commerce covers several classes of porcelain, which ranges from zero to a small fraction of 1 per cent in pore space to vitrified paving bricks which have an unfilled pore space of 3 or more per cent of the total volume.

In order to determine the individual effects of some of the minerals that occur in clays, a large number of mixtures of these minerals have been studied. Those which are of the most common occurrence and produce the most marked effect are as follows:

1. Clay substance.
2. Quartz.
3. Feldspar.
4. Mica.
5. Iron compounds.
   a. Oxides.
   b. Sulphides.
   c. Carbonates.
   d. Silicates.
6. Lime compounds.
   a. Carbonates.
   b. Sulphates.
7. Magnesia compounds.
8. Alkalies.
9. Titania compounds.
10. Sulphur compounds.
    a. Sulphides.
    b. Sulphates.
11. Carbon compounds.
    a. Vegetable matter.
    b. Bituminous matter.
    c. Fixed carbon.

Clay Substance

There are a large number of hydro-silicates of alumina which are always present in clays. While these minerals vary considerably in the proportions of the elements present, they are all of the general type represented by the mineral kaolinite, and in order to simplify chemical calculations they are grouped together and given the formula of kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). This group of minerals is called clay substance. When pure, it is very refractory and burns to a pure white color. The presence of very small amounts of impurities, however, will materially affect both its refractoriness and its color.

It is to this group of minerals that the plastic properties of clays are attributed. The water indicated in the formula is chemically combined and is not removed by the usual methods of evaporation, but is driven off when the mineral is decomposed at a temperature of from 800 to 900 degrees Fahrenheit. When this decomposition takes place, the character of the mineral is altogether changed, and the property of plasticity is lost. All clays contain this chemically combined water in proportion to the amount of clay substance present, the water content varying from about 3 per cent to 14 per cent or higher. The removal of this water, together with the last traces of the mechanically held water, is accomplished in the process of burning clay products.

Quartz

This mineral is found free in varying degrees of fineness in practically all natural clays. Quartz or sand is not at all plastic, and its presence in clays will reduce the plasticity of the mass. It will also reduce the amount of shrinkage which the mass shows on drying and burning. Quartz and other forms of pure silica are highly refractory when pure, but form eutectic mixtures with clay substance, and hence at high temperatures have a fluxing action when present in clay. This fluxing action is proportional to the fineness of the silica present. If silica is present in too large a quantity it will produce a brittle ware when burned; and, due to its erratic property of expanding at certain temperatures, it is apt to produce a ware that will warp and crack. Thus, while in many respects it is a very desirable constituent, it will condemn a clay for commercial purposes if present in too great a proportion. The maximum amount allowable cannot be set at any definite figure, however, since the effect of the silica will be influenced both by the other constituents present and by the form in which the silica itself is present. The use for which the clay is intended will also govern this to some extent; the amount of silica allowable in a clay for making common bricks may be much greater than the amount allowable for making finer products, such as pottery.

The percentages of silica[2] found in Texas clays are as follows:

[2]Table shows average of analyses included in U. T. Bulletin No. 102 by H. Ries and the silica as shown represents the amount of SiO_2 shown by analysis minus that amount considered to be combined in the clay substance.

	All Texas Clays	Fire Clays	Stoneware Clays	Calcareous Clays	Loamy Brick Clays
Average	66.08	68.02	70.22	52.54	80.17
Maximum	91.10	83.00	78.22	82.44	90.00
Minimum	18.62	57.00	63.30	18.62	68.50

Feldspar

This mineral is a complex alumnio-silicate which has the general formula $RO \cdot Al_2O_3 \cdot 6SiO_2$. In this formula the RO represents one or more of the following basic oxides: Na_2O, K_2O, or CaO. All of the feldspars are attacked more or less readily by weathering forces, and as a consequence large amounts of undecomposed feldspar are rarely found in clays, but small amounts of orthoclase, or potash feldspar, are frequently found. Orthoclase is the form most frequently found, both because it is the form which is most abundant in granite rocks and because it is the most resistant to weathering forces. Feldspar grains are of a sandy nature, and affect the texture, plasticity, and shrinkage of unburned clay in much the same way as silica. Its melting point, however, is low, and it ceases to behave like silica when the temperature gets to such a point that the fluxing action of the feldspar begins. Feldspar does not form eutectic mixtures with clay, so its fluxing action is very slow at first and increases in magnitude as the temperature advances. It promotes the chemical reactions of the other constituents and lowers the vitrification temperature. Due to the gradual nature of its action, feldspar is classed as a "safe" flux; that is, it will not cause a short vitrification range which will result in deformation of the ware if somewhat overburned. It is not an objectionable constituent if present in small amounts, and it is a necessary constituent of some classes of products.

Pure feldspar begins to melt at about 1,200 degrees Centigrade, but its fluxing action in some mixtures begins at a much lower temperature. It exerts no appreciable coloring effect on the fired clay mass.

Mica

This is one of the few mineral components of clay which can be detected by the unaided eye. The characteristic bright surfaces of the thin, scaly particles cause this mineral to be very conspicuous, even though the total quantity of the particles may be small. There are several species of this mineral, all of which are complex silicates of alumina in combination with other bases. Muscovite and biotite are the most common forms of its occurrence, and of these two muscovite is the form most generally found in clays.

Nearly all clays contain small amounts of mica, and in some instances the percentage is quite large. Its behavior in ceramic mixtures during burning is very peculiar. Pure muscovite fuses at about 1,370 degrees Centigrade (cone 12), but the size of the particles exert considerable influence on the temperature at which the mineral melts. Stull[3] has shown that very fine mica exerts a fluxing action as low as cone 4 (1,210 degrees Centigrade), and that the pure mineral can be completely vitrified at about this temperature. On the other hand, a German investigator, Rieke,[4] found that the addition of 20 per cent of mica to pure kaolin reduced the fusion point only one cone (from cone 35 down to cone 34), and that the addition of 40 per cent mica reduced it only three cones. It is strange that a mineral with as low a melting point as mica should have no more effect than that indicated when mixed with a very refractory mineral like kaolin. It is evident from these investigations that the vitrification range of mica is long.

Muscovite exerts no appreciable coloring effect on ceramic mixtures, and in some instances will improve the burning properties.

Iron Compounds

There are a number of different forms in which iron may occur, and very few natural clays are found that are entirely free from this element. It is the great coloring agent of clay in both the raw and the burned state. It occurs in clays in the form of the oxide (hematite, limonite, and magnetite), the silicate (biotite, hornblende, garnet, and glamonite), the sulphide (pyrite, marcasite, and pyrrhotite), the sulphate, and of the carbonate (siderite).

The red oxide—hematite—and the yellow oxide—limonite—are probably the most common forms in which iron occurs. They are widely distributed in clays, and are responsible for the red and yellow colors of natural clays and the red colors that are produced in the burned products. The depth of the color produced is dependent upon the amount of iron present and the uniformity of its distribution. The color of the burned products is influenced considerably by the presence of other minerals, especially lime, and by the condition of the kiln atmosphere. The presence of uniformly distributed hematite produces a burned color varying from

[3]Stull, Trans. Amer. Cer. Soc., Vol. IV, p. 255.
[4]Sprechsaal, 1908, p. 578.

a light buff to a dark red. If lime is present it will react with the iron at the vitrification point to produce a lightly-colored complex calcium ferro-silicate and the coloring effect of the iron will be reduced in proportion to the extent of this reaction. The colors produced vary from brown buffs to muddy browns, and if complete vitrification is reached, these colors change to yellow-green. Alumina also exerts a bleaching effect on the iron colors, but it is not as strong as that of lime. Alumina also tends to prevent the reduction of the buff and red colors of ferric iron to the brown and black colors of the ferrous form.

Limonite is a hydrated form of ferric oxide. In the burning process it loses its water of hydration and returns to the ferric form. Its effect upon burned clay is therefore the same as that of hematite.

Under reducing kiln conditions, or if the clay contains carbon in any form which will exert a reducing action, the ferric oxide is reduced to the ferrous form according to one or both of the following reactions:

$$Fe_2O_3 + CO = 2\,FeO + CO_2$$
$$Fe_2O_3 + C = 2\,FeO + CO$$

The presence of ferrous oxide in the clay during the burning process is undesirable. Its brownish colors, changing to yellow-green on vitrification, are not of a pleasing appearance. In addition, it reacts with silica and produces a fusible compound which is an active flux at relatively low temperatures. This fluxing action may close the pore space before the burning process has been completed, and the subsequent formation of gaseous products will cause the ware to bloat and to develop a vesicular structure. The reduction to the ferrous form is accompanied by a decrease in volume, but the space which is formed is in turn closed by the shrinkage in the clay mass. If the ferrous oxide is then reoxidized, it will expand to the original volume. If the iron is uniformly distributed throughout the mass, this action may not cause trouble, but if it is concentrated in small lumps or granules, the force of the expansion may be sufficient to break the bond of the ware. Small lumps of ferrous oxide which are just under the surface frequently develop sufficient pressure in changing to the ferric state to flake off the ware in circular discs.

Magnetite is a mixture of ferric and ferrous oxides in molecular proportions, and in the burning process it will exhibit the properties of both forms. In an oxidizing atmosphere the ferrous portion is readily converted to the ferric form, and this is desirable. Magnetite, however, is not of such common occurrence in clays as are both hematite and limonite.

When present as a silicate, iron is always in some complex combination with other bases. It may be present in either the ferric or ferrous forms, or both, but the ferrous form is nearly always present. In the silicate form it always acts as a fluxing agent, but the rate at which this action proceeds and the temperature at which it begins will depend upon the particular mineral form present. When ferrous iron is present as a silicate, it is practically impossible to oxidize it to the ferric state.

Iron sulphide is frequently found in natural clays. The most common form is iron pyrite or marcasite (FeS_2). This mineral has a very definite crystalline structure, a yellow or golden color, and a glistening metallic lustre. The sizes of the particles vary from minute granules to nodules of an inch or more in diameter. Pyrrhotite (approximately $Fe_{11}S_{12}$) is occasionally found, but its occurrence is rare. The sulphides of iron oxidize readily and form iron sulphate, and weathered clays containing the sulphide will usually be found to contain some of the sulphate.

In the burning process the sulphides begin to decompose at about 350 degrees Centigrade with the formation of ferrous sulphide and an oxide of sulphur. As to whether sulphur dioxide or sulphur trioxide is formed depends upon the amount of oxygen in the kiln gases, the temperature, and the catalytic action of the other minerals present. The reactions for the decompositions are as follows:

$$FeS_2 + O_2 = FeS + SO_2$$
$$\text{or } 2\,FeS_2 + 3\,O_2 = 2\,FeS + 2\,SO_3$$

The iron sulphide which is formed in these reactions will begin to change to the oxide or to the sulphate at about 500 degrees Centigrade. The possible reactions involved in this change are:

$$2\,FeS + 5\,O_2 + SO_2 = 2\,Fe_2O_3 + 4\,SO_2$$
$$4\,FeS + 7\,O_2 = 2\,Fe_2O_3 + 4\,SO_3$$
$$4\,FeS + 9\,O_2 = FeSO_4$$
$$FeS + 2\,O_2 = Fe_2(SO_4)_3$$

The oxides of sulphur thus formed will combine with any water which is being driven from the clay at the same time. This combination forms a strong acid which, if allowed to condense on the ware in the cooler parts of the kiln, will react with the basic minerals such as lime, magnesia, alumina, the alkalies, and iron. Jackson[5] has shown that there is not as much sulphur absorbed from the kiln gases as was expected, but that a small amount does react with the bases present in the clay, even when the concentration of the sulphur oxides in the gases is low. This reaction produces soluble salts in the ware, which may produce a scum or efflorescence. In an oxidizing kiln atmosphere the iron sulphates begin to decompose at about 560 degrees Centigrade, according to the following equations:

$$Fe_2(SO_4)_3 = Fe_2O_3 + 3\,SO_3$$
$$2\,FeSO_4 = Fe_2O_3 + SO_2 + SO_3$$

But if the kiln atmosphere is deficient in oxygen or if carbon is present in the clay, the decomposition will proceed as follows:

$$Fe_2(SO_4)_3 + 3\,CO = Fe_2O_3 + 3\,CO_2 + 3\,SO_2$$
$$Fe_2(SO_4)_3 + 3\,C = Fe_2O_3 + 3\,CO + 3\,SO_2$$
$$FeSO_4 + CO = FeO + CO_2 + SO_2$$
$$FeSO_4 + C = FeO + CO + SO_2$$

and under more extreme reducing conditions:

$$Fe_2(SO_4)_3 + 4\,C = 2\,FeO + 4\,CO + 3\,SO_2$$
$$FeSO_4 + 2\,C = FeS + 2\,CO_2$$

The carbonate of iron, siderite, when present in clay, usually occurs in the form of nodules of a ball-like shape, which vary in size from small granules to boulders of large dimensions. The formation of these nodules is of a secondary nature, soluble iron salts carried in by ground water being precipitated around a nucleus such as a sand grain or another nodule which has already begun to form. As a consequence, such nodules are found to be made up of a number of layers formed concentrically about a nucleus. They should be avoided as far as possible in the mining of clay, but the smaller ones cannot be thus discarded, and will be ground and mixed with the clay in the manufacturing process. While the nodules will be ground along with the clay, they will not be so

[5]F. G. Jackson; J. Amer. Cer. Soc., Vol. 9, p. 154, 1926.

finely pulverized and will be present in the molded ware in comparatively large particles. During the burning process these particles will be decomposed at a low temperature, as follows:

$$FeCO_3 = FeO + CO_2$$

It is very difficult to oxidize these small lumps of ferrous oxide to the ferric state, and ware which contains siderite will usually contain spots when burned. If the temperature is carried high enough these spots will fuse and form a black slag in the immediate vicinity of the original granule.

No definite limits can be placed upon the iron content of a clay except with reference to the particular class of ware for which the clay is intended. If white ware or porcelain is to be manufactured, iron in any quantity is undesirable, and even a few tenths of 1 per cent may be sufficient to condemn the clay. Clays for refractory purposes cannot carry much iron because of the fluxing action. The following table[6] shows the percentage of iron found in Texas clays:

	All Texas Clays	Fire Clays	Stoneware Clays	Calcareous Clays	Loamy Brick Clays
Average	2.74	0.64	1.51	2.77	8.24
Maximum	16.60	1.54	4.75	6.20	16.60
Minimum	0.14	0.21	0.43	0.75	4.06

Lime Compounds

Nearly all clays contain at least a trace of lime. It is usually present as the carbonate. Some Texas clays contain a small percentage of the sulphate of lime. Lime may occur as the silicate, but as such is very rare in Texas clays.

Limestone, or calcium carbonate, is both the most abundant form of lime and the form which exerts the greatest influence upon the burning properties of clays. Pure limestone, heated in a closed vessel, will dissociate into calcium oxide and carbon dioxide according to the equation: $CaCO_3 = CaO + CO_2$. At any given temperature an equilibrium will be established between the tendency of the calcium carbonate to dissociate and that of the products of dissociation to recombine to form calcium carbonate. At ordinary temperatures and atmospheric conditions the partial pressure of CO_2 in the air is much greater than the pressure of the CO_2 that

[6]Ries; U. T. Bull. 102, page 32.

would be produced by the dissociation of limestone. The carbonate is, therefore, the most stable form under these conditions, and CaO, if exposed to the air, will absorb CO_2 and pass into the carbonate form. As the temperature is increased, the pressure of the CO_2 from the dissociation increases, until at 600 degrees Centigrade it is equal to the partial pressure of the CO_2 which is normally present in the atmosphere, and at 898 degrees Centigrade it is equal to the total atmospheric pressure under normal conditions. This latter point is called the *dissociation temperature.*[7] Limestone, however, is seldom pure calcium carbonate, and the presence of impurities tends to lower the dissociation temperature. Bleininger and Emley[8] found the dissociation temperature of an impure limestone to be as low as 880 degrees Centigrade.

In the ordinary ceramic kiln, limestone begins to decompose at about 600 degrees Centigrade, and is completely converted to the oxide by the time a temperature of 900 degrees Centigrade is reached. The CO_2 passes off in the kiln gases and the CaO, or quicklime, remains in the ware. If the amount of lime present is small and it is uniformly distributed through the clay, it will have little or no effect on the burning properties. It may absorb water or CO_2 from the air after the ware is removed from the kiln, but as long as the individual particles are small there will be no noticeable effect.

As the temperature in the kiln rises, the lime will tend to react with the silica, alumina, and iron in the clay, and will produce mineral compounds which are very fusible. When it unites with iron and silica to form the complex calcium ferro-silicate, the coloring effect of the iron will be reduced, as has already been discussed. The reduction of the iron color is greatest when the proportion of calcium to iron is about three to one. If the lime and iron are present in about equal amounts, little or no bleaching action is evident. Lime also forms several easily fusible eutectic mixtures with alumina. It is this fluxing action of lime which causes the greatest difficulty in burning high lime clays. It has been shown that in clays which contain a high percentage of lime the points of incipient fusion and viscosity—the limits of the vitrification range—

[7]Johnson, J.; J. Amer. Cer. Soc., 32, 8, 1910.

[8]Bleininger, A. V., and Emley, W. E.: Trans. Amer. Cer. Soc., 18, 884, 1916.

may approach within 40 degrees Centigrade of each other. It is not economically possible to obtain throughout the kiln space a temperature which is uniform within such narrow limits. A variation of from 60 to 100 degrees Centigrade is considered excellent practice, and in most kilns the difference is much greater. Thus, if a kiln is set with ware made of a high lime clay, a considerable percentage of the ware will invariably be either under or over-burned. Furthermore, very few clays fuse quietly, and when the action is as rapid as it is in such high-lime clays, it will more than likely develop gaseous by-products, which in turn will produce a vesicular structure or even distortion of the ware. Hence, clays containing sufficient quantities of lime to produce such effects cannot be used for the manufacture of ware other than common brick and cannot be burned much above 900 degrees Centigrade.

Limestone, in the form of large lumps such as gravel, is undesirable even when present in clay in very small amounts. When present in this form, it is impossible to screen it out of the clay or to mix it thoroughly with the clay. These lumps, though converted to the oxide on heating, do not enter into combinations as readily as the finely divided and uniformly distributed lime, but the unchanged lumps of quicklime will remain in the burned ware. Lime, by itself, is fairly refractory, and such lumps retain their identity even though heated considerably above 900 degrees Centigrade. Upon cooling, these lumps will first absorb moisture from the air and slake, and then take up CO_2 from the same source, and return to the original carbonate form. Both of these changes are accompanied by an increase in volume. A single small lump in the center of the ware may not exert sufficient pressure to cause any damage, but a large lump or several small lumps located close to each other will soon develop sufficient pressure to break the bond of the ware. Lumps located close to the surface will also tend to cause a flaking which produces an unsightly and uneven surface.

Lime in the form of the hydrated sulphate known as gypsum is of common occurrence, though the amounts present in clays are seldom large. Its presence in clays is thought to be due to the decomposition of iron pyrites by weathering and the subsequent action of the sulphuric acid formed upon the calcium carbonates present in the clay. It may also be formed in the ware by the action

of sulphur trioxide from the kiln gases upon the calcium carbonate in the clay. Damp ware and poor draft are favorable to this reaction. Calcium sulphate thus formed in the ware collects on the surface in a white scum known as kiln white.

Gypsum begins to lose part of its water of crystallization when heated to 100 degrees Centigrade and is converted into the form known as plaster of Paris. This form will readily reunite with water to return to the gypsum form. When heated above 200 degrees Centigrade, however, it loses all of its water and goes to the form known as anhydrite, which form is very slow to rehydrate. In an oxidizing atmosphere no further change occurs in the gypsum until a temperature of 1,210 degrees Centigrade is reached. At this temperature it begins to dissociate into calcium oxide and sulphur trioxide, and the reaction becomes quite rapid at a temperature of 1,325 degrees Centigrade.[9] This temperature is considerably higher than the vitrification point of most red burning clays, and the sulphur trioxide evolved is likely to cause bloating of the ware and produce a vesicular structure. Under reducing kiln conditions the decomposition of anhydrite takes place at much lower temperatures. Seger[10] states that sulphuric acid which has been absorbed by the ware can be reduced and expelled from the kiln as sulphurous acid, and Williams[11] was able to reduce gypsum in an atmosphere of carbon monoxide as low as 800 degrees Centigrade. In commercial practice the temperature of the kiln in the coolest part should reach 700 degrees Centigrade, and the reduction should not be great enough to produce calcium sulphide. Bole and Jackson[12] recommend the following procedure: First, reduce the sulphate present to the sulphite ($CaSO_4 + CO = CaSO_3 + CO_2$). Next, dissociate the sulphite by further heating ($CaSO_3 = CaO + SO_2$). Then follow with a reoxidizing period to restore any iron present to the red color of the ferric form. The CaO produced by the reduction and decomposition of the anhydrite will remain in the clay and have the same effect as described above for lime from the carbonate.

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[9]G. A. Bole and F. G. Jackson; J. Amer. Cer Soc., 7. 427, 1924.

[10]H. Seger; "Collected Writings," 1, 128.

[11]A. E. Williams; Trans. Amer. Cer. Soc., 18, 271, 1916.

[12]Same as note 9 above.

Lime in the form of the silicate is not of such common occurrence as the carbonate or the sulphate, and its presence is not as objectionable as that of the other forms. While the silicate is an active fluxing agent, its action is much slower, and the points of incipient fusion and viscosity are not in such dangerous proximity to each other. Furthermore, there is no gaseous product formed by its fusion which will bloat or deform the ware. Lime as the silicate is always associated with some other base, and the temperature at which its fluxing properties become active depends upon the particular base which is involved.

Many conflicting statements have been made regarding the allowable limits of lime that may be present in clays that are to be used for commercial purposes. Some writers contend that the lime content should not exceed 3 per cent. Seger makes the statement that as much as from 20 to 25 per cent may be present and not be detrimental to the manufacture of common bricks, provided it is present in a finely divided and uniformly distributed condition. As a matter of fact, the effect that a given amount of lime will have on any particular clay depends upon so many variable factors that it is impossible to set any definite limit. Good grades of common brick are being manufactured in this State from clays that carry as high as 49 per cent of calcium carbonate. In the end, the commercial use for which the clay is intended and its behavior when tested to determine its fitness for this purpose will be the determining factors. The following table[13] shows the lime content of the clays tested:

	All Texas Clays	Fire Clays	Stoneware Clays	Calcareous Clays	Loamy Clays
Maximum	41.30	2.10	3.40	41.30	4.10
Minimum	0.00	0.08	0.00	5.32	trace
Average	3.63	0.36	0.63	17.89	0.75

Magnesia

Magnesia seldom occurs in clays in quantities greater than 1 per cent. When present, it is usually in the form of the silicate, although it sometimes occurs both as the carbonate and the sulphate. The siliceous minerals—biotite, hornblende, chlorite, and

[13]H. Ries; U. T. Bull No. 102, p. 38.

pyroxene—all contain magnesia. All of these minerals are more or less readily decomposed by the action of weathering, and the magnesia converted into a soluble salt. The soluble salt thus formed may be leached out or may be retained in the pores of the clay in the soluble form. When present in the carbonate form, magnesia is usually associated with calcium as the double carbonate "dolomite." The sulphate of magnesia is seldom present in any quantity in clays, due to its great solubility, and when present is usually the result of the reaction of the carbonate with sulphuric acid resulting from the decomposition of pyrites, just as in the case of gypsum. Magnesium sulphate in clay is very likely to form a white scum on the surface of the water. It will be dissolved in the tempering water, and will then be carried to the surface and deposited there as the water evaporates during the drying process.

All magnesium compounds exert a fluxing action when present in clays, but do not bring on the rapid softening which is characteristic of calcareous clays. As the percentage of magnesia increases it passes more quickly to its refractory properties and retards rather than accelerates vitrification. It has been found that as little as 1 per cent of magnesium oxide exerted a beneficial effect in porcelain bodies by causing them to mature at lower temperatures.[14] But it also caused them to overfire at a correspondingly lower temperature.

Magnesia does not exert as strong a bleaching action on the iron colors as does lime. An important characteristic of magnesian clays is that they can be made into ware of extreme length with very thin walls, which may then be nearly vitrified without warping.[15] Parmelee and Bleininger[16] have found that magnesia mixtures in porcelain bodies and slags produce a longer fusion range than lime, and develop a tough body which is subject to less distortion. However, Lovejoy[17] says that this action of magnesia has not been borne out in his experience of adding magnesia to paving-brick materials, but that, on the contrary, when magnesia is present in such quantities as lime would be, it shortens the vitrification range in the same way. Vitrified common wares, however, are not

[14]F. H. Riddle and W. W. McDaniel; J. Amer. Cer. Soc., 1, 606–627, 1918.
[15]E. Bourry; "Treatise on the Ceramic Industries," Van Nostrand, 1901.
[16]W. C. Parmelee and A. V. Bleininger; Trans. Amer. Cer. Soc., XVI.
[17]E. Lovejoy; "Burning Clay Wares." T. A. Randall & Co., 1922.

carried to the same degree of fusion as are porcelain bodies, and it is yet to be proven whether the addition of magnesia to vitrifying materials, which contain neither lime nor magnesia in appreciable quantities, will lengthen the vitrifying range or produce a better product.

Very little has been said regarding the allowable limits of magnesia that may be present in a commercial clay. The probable reason for this is that it seldom occurs in appreciable quantities. Its presence in fire clays and refractory materials, except the magnesian refractories, is undesirable. It has been found that magnesia compounds exert a large influence on clays which contain a number of active fluxes and which vitrify at a low temperature, but as the number and character of the fluxing bases change toward that of a more refractory nature, this influence decreases rapidly.

The variation in the percentages of magnesia as found in Texas clays which have been examined are as follows:[18]

	All Texas Clays	Fire Clays	Stoneware Clays	Calcareous Clays	Loamy Clays
Maximum	7.16	3.01	7.16	2.23	1.56
Minimum	0.00	trace	0.18	0.15	trace
Average	0.94	0.45	1.28	0.93	0.53

The Alkalies

The oxides of sodium and potassium are generally included under the term of "alkalies." Most clays will usually contain small amounts of these bases, but the percentage is seldom large. They are usually present as basic components of complex silicates, such as glauconite, hornblende, feldspar, and muscovite.

The alkalies alone exert no coloring effect on either raw or burned clay, but sometimes potash seems to increase the coloring action of iron. The chief effect of the alkalies is their fluxing action. They are the most active fluxing materials found in clay, and for this reason their presence is very undesirable in clays intended for refractory purposes. In clays intended for other classes of ware their presence is not harmful, and in some cases is desirable. On account of their fluxing action they serve to bind the less fusible particles of the clay mass together into a dense body and permit the formation of a vitrified body at a much lower tem-

[18]H. Ries; U. T. Bull. No. 102, p. 38.

perature than would otherwise be possible. Potash, in the form of feldspar, is added to porcelain and white ware bodies to produce a vitrified product at commercially attainable temperatures.

As stated above, the alkalies may be present in any one of several different mineral forms. Each of these minerals has its own individual characteristics, and their melting points vary considerably. The temperature at which the alkalies will begin to act will thus depend upon the particular mineral present. The physical condition of the mineral will also affect its action, and other minerals present may have some influence on the result. In general, however, it seems that the alkalies do not have as much tendency to form eutectic mixtures as do some fluxing materials. Their fluxing action is slow, producing a long vitrification range. Other things being equal, soda is the more active base, but its vitrification range is about as long as that of potash. Watts[19] has found that there is practically no difference in the degree of vitrification, warpage, and quenching resistance when soda feldspar is substituted for potash feldspar in porcelain mixtures.

The percentage of alkali is usually lowest in kaolins and fire clays, and highest in brick clays and slip clays. The following tables[20] will give some idea of the amount of alkalies present in Texas clays. It will be noted that the average percentage of both potash and soda is less than 1 per cent, but these averages are somewhat lower than would be obtained by averaging a number of clays from all parts of the State.

Soda in Texas clays examined:

	All Texas Clays	Fire Clays	Stoneware Clays	Calcareous Clays	Loamy Clays
Maximum	4.10	1.70	1.17	4.00	1.56
Minimum	0.00	0.10	0.10	0.00	trace
Average	0.82	0.63	0.87	0.93	0.37

Potash in Texas clays examined:

	All Texas Clays	Fire Clays	Stoneware Clays	Calcareous Clays	Loamy Clays
Maximum	2.71	0.60	2.58	1.80	2.40
Minimum	0.00	trace	0.12	0.00	trace
Average	0.86	0.12	0.77	0.46	0.32

[19]A. S. Watts; Trans. Amer. Cer. Soc., XI, p. 179 and 197, 1907.

[20]H. Ries; U. T. Bull. No. 102, 39.

Titanium

The general chemical analysis as commonly made rarely shows this element to be present, and yet there are very few clays which are entirely free from it. It is not generally determined in such analyses both because of the difficulties attendant upon its determination and because its importance is not generally recognized. Of those Texas clays which have been examined for it, it has been found in practically every one in amounts varying from a trace to a maximum of 2.08 per cent.

Titanium may occur in combination with iron in the form of ilmenite ($FeO \cdot TiO_2$) or it may occur as the simple oxide in the mineral form rutile (TiO_2). In the chemical analysis it is reported as the oxide. Its coloring effect is very feeble, and the amount that is usually present is so small that its effect cannot be noticed. In sufficient quantity, however, and when mixed with white-burning clays or glazes, it produces light buff or straw colors of displeasing character. According to Audley,[21] titanium augments the red color due to the iron compounds.

The chief characteristic of titanium is its fluxing action, which, however, does not become active until the higher ranges of temperature are reached. It has been shown[22] that if 1 per cent of titanium oxide is added to a highly refractory clay, the fusion point will be reduced one cone of the Seger series, while 4 per cent will reduce it one and one-half cones and 5 per cent will reduce it two and one-half cones. It is, therefore, evident that the titanium content is an important factor in determining the value of a clay for refractory purposes.

The variation in the amount of titanium that was found in a series of Texas clays is shown in the following table:[23]

	All Texas Clays	Fire Clays	Stoneware Clays	Calcareous Clays	Loamy Clays
Maximum	2.12	2.12	1.5	1.05	1.57
Minimum	trace	trace	0.25	0.00	0.32
Average	0.97	1.11	1.15	0.62	0.86

[21]J. A. Audley; "Silica and Silicates," p. 76. Van Nostrand, 1921.
[22]N. J. Geol. Surv., Vol. VI, p. 70, 1904.
[23]H. Ries; U. T. Bull. No. 102, p. 41.

Sulphur

Sulphur occurs in clays as both the sulphide and the sulphate. Its effect on the burning properties of clays has been discussed under the head of iron and calcium, as these are the two bases with which it is usually combined. While sulphur is an undesirable constituent, its presence need not condemn a clay for use. Its compounds are fairly easily decomposed at temperatures which are below the vitrification range, and if proper precautions are taken during the initial stages of the burning process, it can usually be eliminated. But all of the sulphur must be expelled before the vitrification period is reached. At the temperature of vitrification silica becomes a very active acid and will displace the sulphur from the base with which it is united. In this reaction the sulphur is expelled in the form of a gas, and if the pore space has been sufficiently closed by the vitrification process to prevent the escape of this gas, trouble will be caused by the formation of blisters and the development of a vesicular structure. The presence of organic matter greatly augments the effect of the sulphur, since it tends to reduce any iron present to the ferrous condition which, in turn, hastens the vitrification of the clay.

Carbonaceous Matter

Carbon is frequently present in clay. It occurs in the form of vegetable matter (wood, leaves, etc.), bituminous matter, and fixed carbon. It also occurs in combination with other elements as the carbonate. Its action in this form has been discussed in connection with the bases with which it is associated.

Vegetable matter is commonly found in surface clays of recent origin. It rarely affects the color of the raw clay. The larger pieces may be eliminated in the mining of the clay or by screening. The small amount which will be passed through the screens will burn readily and is not apt to give much trouble.

Bituminous matter is vegetable matter that has undergone changes due to its burial within the clay, out of contact with air. It is found in some clays, but occurs more generally in connection with shales. Examples of its occurrence in Texas clays are the lignitic

clays of the Tertiary and the carboniferous shales of the Pennsylvanian. The Eagle Ford shale of the Comanchean also carries some bituminous material.

Bituminous matter exerts a large coloring effect on the raw clay, and varies from gray to black according to the amount that is present. Very small quantities are frequently sufficient to mask completely the original color of the raw clay. The bluish-green color of some shales is thought to be due to ferrous iron, but in many cases it is caused by a small amount of carbonaceous matter.

Carbonaceous matter begins to burn at low red heat (about 600 degrees Centigrade), and its combustion requires oxygen. This oxygen is taken from the kiln atmosphere or from reducible compounds in the clay. Hence, there is little opportunity for those compounds in the clay which require oxygen for their development to obtain any until all of the carbonaceous matter has been burned. Little trouble will arise from this source if the amount of such matter is small, and care is taken during the buring period to hold the temperature down until all of the free carbon has been burned. An opportunity must then be provided for the reoxidation of any iron to the ferric state before the vitrification period is reached. If these precautions are not observed, the outer surface of the ware may be partly vitrified and become so dense that no oxygen can pass through it. If the burning process is stopped at this point, the ware will have a black center or core due to the presence of unburned carbon or ferrous iron. If the heating process is continued, the carbon will take oxygen from the iron and the carbon monoxide formed will bloat and distort the ware.

Bituminous matter burns readily, due to the highly combustible gases which are produced. These gases, however, will generate considerable heat in burning at the surface of the ware, and may cause premature vitrification to take place on this surface.

Fixed carbon occurs mostly in shales, and is formed from vegetable matters by a continuation of the same process of heat and pressure beneath the earth's surface which forms the shale. By this process all the combustible gases or hydrocarbons such as are present in bituminous matter are eliminated. Fixed carbon effects the properties of clay in much the same manner as bituminous matter, except that it burns more slowly. Thus, it requires longer heating

to eliminate it, but the slowness of the reaction makes it more easily controlled and there is less danger of the injurious effects caused by bituminous matter.

The amount of carbon that may be present in clays will depend upon the form in which it occurs, and upon the physical characteristics of the clay. Shales containing as high as 10 per cent of carbonaceous matter have been burned successfully, but if a clay has a tendency to become dense at low temperatures, this tendency is increased by carbonaceous matter, and as low as 3 per cent may give trouble. There is no data available on the carbon content of the Texas clays.

IV. Physical Properties of Clay

While the chemical properties of a clay exert a large influence on the physical properties, yet a knowledge of the chemical composition alone is of very little value in determining the commercial possibilities of a great majority of clays. The chemical effects of the various mineral constituents have been discussed, but the effect of each constituent mineral is so greatly modified by the presence of other minerals that it is impossible to predict the exact effect that it will have in the mixture. From the commercial standpoint, the factors that determine whether a clay can be fabricated, and the use for which it is best adapted, are the plasticity, slaking properties, tensile strength, shrinkage, porosity, absorption, fusibility, texture, color, and specific gravity. The chemical composition will exert some influence on nearly all of the properties, but in no case can the property be predicted with any degree of accuracy from the chemical analysis alone. The color of the finished product can be estimated from the iron content, and the fusibility approximated from the amount of fluxes, but it is impossible to say that a certain percentage of iron will produce a certain color or that the product will melt at any definite temperature.

The properties enumerated above are known as the *physical properties* of the clay, and are determined by a series of physical tests. These tests have been carefully studied and standardized by the American Ceramic Society. In most cases these tests are all that is necessary to determine the commercial possibilities of a clay. In testing clays for white ware and refractory purposes, the

chemical analysis is usually made in addition to these tests, although it is not absolutely necessary, except where it is desired to calculate the proportions for a synthetic body. The chemical analysis is also made in a few special cases when it is thought that such an analysis may throw light upon the cause of, or assist in correcting, certain faults which develop when the clay is burned.

Plasticity

This is one of the most important properties of a clay, as it is this property which enables it to be molded into any desired form. The degree of plasticity is a measure of the ease with which the molding can be accomplished. Plasticity is defined as that property which enables a material to be deformed continuously and permanently without rupture during the application of a force which exceeds the yield value of the material.

The testing of the plasticity of a clay by feeling the moistened material and judging it to be good, fair, medium, or poor, is obviously an empirical method, and depends upon the judgment and experience of the operator. Many efforts have been made to devise mechanical means of determining the plasticity, but none which have been suggested thus far are entirely satisfactory. Some experimentors have endeavored to form a relationship between the plasticity and the tensile strength of the clay, but clays which are highly plastic frequently have a very low tensile strength, and a conclusion reached by this means in these instances would be misleading. Others have considered that the plasticity depends upon the proportions of colloidal matter present, but the facts fail to bear out this assumption. Still others have tried to relate the plasticity to the quantity of water required to make the clay up to a certain consistency, but tests by this method are found to produce very erratic results. These three methods are only a few selected at random from a large number of methods which have been proposed, but most of them fail in some respect when applied to a large number of clay samples.

No satisfactory explanation of the causes of plasticity has yet been advanced, although a number of theories have been advocated, including the plate theory, the colloidal theory, the water of hydration theory, the theory of texture, the interlocking grain theory,

the ball theory, the molecular attraction theory, etc., but none of these has been found to explain all of the facts which have been observed. In all probability, plasticity does not depend upon any one phenomenon. It is more likely to be due to a number of these factors acting conjointly. Hence, it is practically impossible to devise a simple mechanical means which will take into account all of these factors and will give a result which can be translated into terms of plasticity. The old empirical method is still largely used, and, while it is open to serious criticism, it is still the most effective means of getting an accurate comparison between a large number of clay samples.

The plasticity is of interest to the clay manufacturer because it is an indication of the ease with which the clay can be molded into the desired form. For certain types of clay ware it is necessary that the clay have greater plasticity than is required for other types. It is frequently necessary for the manufacturer to mix two clays of different plasticity or to add some non-plastic material in order to produce the desired property in the material used to mold the ware. The most plastic clays among those found in Texas are probably those worked near Dallas and Ferris, which are of the Eagle Ford series. The least plastic ones are the calcareous and loamy alluvial clays which are worked in the various sections of the State. The stoneware and fire clays which occur most generally in the Tertiary series are intermediate between the Eagle Ford clays and the alluvial clays in plasticity.

Slaking Properties

If a piece of raw clay is immersed in a large volume of water, the water will gradually permeate the clay and cause the mass to fall to pieces. This phenomenon is known as "slaking." The action is similar to and derives its name from the slaking of calcined lime in water. Some clays slake very readily, i.e., they begin to fall to pieces almost instantly upon contact with water, and within a relatively short time the entire mass is reduced to a soft, mushy consistency. On the other hand, some clays show very little tendency to slake, and even after being immersed in water for some time they show little evidence of such disintegration. The time required for the slaking of a clay depends upon its porosity and the cohesion

of its particles. A soft, porous, "lean" clay may be completely slaked in a very short time, whereas a highly plastic or "fat" clay, which is of a dense nature and possesses very small or very few pores, may not be fully disintegrated even after the lapse of several weeks in contact with water.

The readiness with which a clay slakes is very important to the manufacturer, as it is a direct indication of the ease or difficulty which he may have in "tempering" or mixing the clay with the proper amount of water to produce the desired plastic condition. If the clay slakes readily, the mere mixing with water may be all that is required, and a very small amount of "pugging" may suffice to make the mix homogeneous and prepare it for the molding process. On the other hand, if the clay slakes with difficulty, more grinding equipment must be installed in order to effect a preliminary disintegration of the clay before it is mixed with water, and a considerable amount of tempering equipment must be used in order to work the clay into a plastic and homogeneous mass.

Tensile Strength

Tensile strength is the force required to produce a rupture due to tension. This value is tested in a special machine. The clay is molded into bricklets of a specified form, the bricklets are air dried, and are then pulled apart by the machine. The machine is designed to measure the force necessary to pull the piece apart. The tensile strength is of importance to the manufacturer of clay ware, as it indicates the ability of the clay to withstand the shocks and strains which it will encounter during the process of manufacture. It also indicates the bonding power of the clay and the extent to which it can be mixed with non-plastic materials.

There is no constant or direct relationship between the tensile strength and the plasticity of a clay. Some clays of high plasticity have a low tensile strength, and clays of moderate or even low plasticity may develop a fairly high tensile strength when dried. As examples of these variations, the following table gives these values for several clays obtained from different parts of the State:

Lab. No	Source	Plasticity	Tensile Strength lbs. per sq. in
801	Austin	Medium	253
807	Saspamco	High	257
813	Seguin	Low	301
827	Rockdale	High	189
828	Rockdale	High	302
849	Malakoff	Fair	99
904	Colmesneil	Low	77
923	Milano Jct.	Low	47

Shrinkage

The shrinkage of clays is of two types: that which takes place during the drying period and that which takes place during the burning of the clay. The first is known as the "air shrinkage" and the second is known as the "fire shrinkage."

When a clay is mixed with water in sufficient quantity to render it plastic, it will increase in volume, and hence when this water is removed during the drying process the volume of the mass will shrink to an extent depending upon the amount of original increase. It is thought that in the plastic state each individual clay grain is completely surrounded and separated from the others by a film of the water which has been added. This water serves as a lubricant so that the grains are free to move over each other. Hence, the clay is in a plastic condition and can be molded into any desired shape. On drying, the water which separates the grains is removed and the clay grains are drawn closer together, thereby causing a decrease in the total volume of the mass.

As soon as the water which envelops the clay grains has been removed and these grains are in contact with each other, the shrinkage ceases. The water which is removed up to this point is known as the "shrinkage water." The clay in this condition has attained considerable hardness and cannot be deformed except by the application of considerable pressure. However, it still contains a relatively large amount of water which fills the interstitial space between the clay grains. This water, known as "pore water," is removed less rapidly than the shrinkage water, due to the slower movement of water toward the surface, but it can be removed below a temperature of 100 degrees Centigrade, and should all be removed before the drying operation is considered complete.

There are two other kinds of water still present in the clay after all the water of plasticity has been removed. These are the "hygroscopic water" and the "chemical water," or "water of constitution." The removal of these waters is accomplished in the burning process, and is discussed later on in Chapter III.

As a general rule, highly plastic clays exhibit high drying shrinkage, and vice versa, the lean or poorly plastic clays show very little drying shrinkage. However, the degree of shrinkage cannot be taken as a criterion of the plasticity, as there are a few instances in which clays of a highly plastic nature have been known to have relatively low drying shrinkage. It may also be said that those clays which require a large amount of water to develop a given plastic condition will have relatively high shrinkages.

The fire shrinkage of clay is due to two causes, both very distinct from the causes of the air shrinkage. The removal of the hygroscopic water does not entail any change in volume. The first step in the fire shrinkage begins when the temperature reaches such a point that the clay molecule is decomposed and the water of composition is removed. There is thus effected a chemical change in the clay which is accompanied by a reduction in the volume. The second step starts when the most fusible constituents of the mixture begin to liquefy and to exert a fluxing action on the other constituents. A fluid matrix is thus formed which fills the interstices between the solid grains, and the volume of the clay mass is reduced in proportion to the amount of such filling-in action. There are several other minor causes which may affect volume changes in clay during the firing process. Any calcium carbonate present will decompose into calcium oxide and gaseous carbon dioxide, with a reduction in the solid volume. If this reaction takes place after the pores of the ware have been closed by the fused matrix, this carbon dioxide gas will be entrapped within the mass and cause bloating and damage to the ware. Any carbonaceous matter present will oxidize and bring about volume changes. In highly siliceous clays there is sometimes a tendency at high temperatures for the silica to be transformed to another crystal form which is accompanied by an increase in volume.

All of these factors must be considered in deciding the adaptability of a clay. Clays which show excessive fire shrinkage must

be mixed with a non-shrinking grog before being fabricated. The range of temperatures at which the ware must be fired is determined by the fire-shrinkage behavior.

Porosity

Porosity refers to the amount of open space or voids that occur between the particles of the aggregate, and may be defined as the ratio of the volume of this open space to the total volume occupied by the clay mass. Porosity is determined by measuring the weight and volume of a dry piece of clay or clay ware, then immersing the piece in a suitable liquid—kerosene oil is used if the slaking effect of water must be avoided—until the liquid has had time to penetrate the pores. The piece is then wiped free from the liquid adhering to its surface, and weighed. The difference between this weight and the dry weight is the weight of the liquid which fills the pores, and from it can be calculated the volume of this pore space. Under such conditions all the larger pores are filled, but there are always some very fine pores which are not penetrated. By this method the volume of the larger, more accessible pores is all that is determined, and this value is known as the "apparent porosity," as distinguished from the "true porosity," which is obtained only when special conditions are employed by which even the most minute pores are filled. The conditions which prevent the smallest pores from being measured by the common porosity test also prevent them from taking any very great part in affecting the properties of the clay, hence the "apparent porosity" as determined is really the value which is of most importance in judging the working qualities of a clay.

The porosity of raw clay is an indication of its drying properties. Since the water which is mixed with the clay to develop plasticity must be dried by evaporation from the surface of the molded product, the system of capillaries which make up the open pore space of the mass and through which the moisture must be brought to the surface for evaporation necessarily exerts a large influence upon the drying properties of the clay. Hence, a clay which is of an open or porous nature can be dried at a more rapid rate and with less danger of rupture due to strains produced by unequal drying than in the case of a dense and non-porous clay. It has been found

that the porosity of fired ware exerts a very definite influence upon the apparent density, spalling tendency, thermal conductivity, resistance to corrosion, resistance to abrasion and erosion, electrical conductivity, dielectric strength, mechanical strength, refractoriness, and discoloration.

Since an increase in the porosity means a larger amount of open space per unit volume, it follows that, as the porosity increases, the amount of solid material per unit volume will decrease and the apparent density of the product will be reduced.

A porous piece of fired ware is not as sensitive to sudden changes in temperature as a denser and less porous piece. Hence, the breaking down of ceramic ware due to sudden changes in temperature is less likely the more porous the structure. The ability to resist these sudden changes in temperature is probably due to the fact that the grains in the more porous mass have more freedom of movement than have those in a denser mass. A high porosity is especially important as a means of securing resistance to spalling in the case of refractory materials which are to be used for high temperatures.

Ceramic materials which have a high porosity usually have a low thermal conductivity. It is well known that small air spaces which do not allow losses by convection currents are excellent insulators. For this reason, porous ware acts as a non-conductor of heat. Hence, if the product is to be used for insulating purposes, a porous structure is desirable, but if it is desired to conduct heat through the material, as in the case of the walls of a retort, a dense structure is required.

High porosity generally reduces the resistance of the ware to corrosion. Pores provide excellent entrances for corrosive gases and liquids into the interior of the ware, and the fewer or smaller these pores, the less opportunity there is for corrosive action. Hence, a dense product is desired for materials that are designed to withstand the action of corrosive gases, slags, etc.

A porous type of structure likewise offers very little resistance to abrasion and erosion, for the reason that the open pores expose a larger surface to the destructive action, and also reduces the total amount of solid matter in a given area or volume to resist this action.

While most ceramic materials are of themselves good insulators, yet it has been found that a porous product has even a lower electrical conductivity than a dense product of the same material. This may be due to the fact that the decrease in the volume of the solid matter per unit volume in a porous product involves an increase in the resistance to the passage of an electrical current, and also to the fact that a considerable part of this volume is air, which is itself a non-conductor. However, some of the best electrical insulators are composed of stoneware and porcelain, which are products that are completely vitrified and devoid of pores.

Since an increase in the porosity necessarily means a decrease in the solid content of the ware per unit volume, and since the strength of the ware depends upon the amount of solid material and the effectiveness of the bond, it follows that an increase in the porosity will bring about a decrease in the mechanical strength. In general, fired ceramic ware will have ample crushing strength, even if quite porous, but under some conditions the porosity must be sacrificed in order to gain strength.

Strictly speaking, there is no connection between the refractoriness of a product and its porosity, but it frequently seems that porous products have a greater refractory value than those of a denser nature. This apparent increase in refractoriness is probably due to their lower thermal conductivity, and hence a longer heating period is necessary in order to produce the same apparent signs of fusion. Furthermore, it is frequently the case that the more porous products are of a coarser texture, and under these conditions the increase in refractoriness is primarily due to the difference in texture.

Porous ware is more likely to become unsightly due to discoloration, than is a non-porous ware, for two reasons: It is more likely to pick up dirt, soot, and fine particles in its surface pores. It is also likely to become discolored through absorption of dissolved salts, which later appear as an unsightly scum on the surface of the ware when it is dried out by evaporation.

Porosity is a measure of the degree of vitrification of ceramic ware. Since vitrification is produced by a fusion of a part of the constituents and a consequent drawing together of the material into a more compact mass, obviously as vitrification proceeds the volume of the pore space in the material is diminished.

Absorption

Absorption and porosity are measures of the same physical property, but expressed in different terms—i.e., the apparent volume of the pore space is determined by the volume of the liquid that is required to fill it—and this is expressed in terms of percentage of the total volume of the object; whereas, the absorption is determined by weighing the object before and after it has been impregnated with the liquid, and the increase in weight—the weight of the liquid absorbed—is expressed in terms of the percentage of the weight of the dry piece.

Fusibility

The fusibility of a clay is the inverse of its refractoriness, or its ability to withstand elevated temperatures. The degree of refractoriness and its behavior under the temperature of the normal firing range is of great importance to the manufacturer of ceramic products. The fusibility of a clay is influenced by its chemical composition and by its texture. Some clays, such as the refractory flint clays of Missouri and high-grade kaolin and china clays do not show appreciable signs of vitrification until extremely high temperatures are reached. Such clays are termed "refractory clays," and may be used for the manufacture of ware which must withstand high temperatures. Other clays have a fair degree of refractoriness, but do vitrify completely without losing their original form. Such clays may be used for the manufacture of stoneware and vitrified products. Some clays have a very short vitrification range and cannot be used for vitrified ware, their use being confined to such ware as may be burned to temperatures below vitrification, and thus has a porous structure when finished. There are a few clays which vitrify to a soft, glassy consistency at relatively low temperatures. These are classed as easily fusible clays, and, if the glass thus formed does not develop a bloated or bleb structure, they may be used as glazes on other ceramic bodies. The well-known Albany slip clay is of this type. It may be seen from these facts that the temperature at which a clay will vitrify or fuse, and its behavior on vitrifying, are properties of great importance in determining the use for which a clay may be adapted.

Texture

The texture of a clay refers to the grain size of the individual particles. The texture is a rough indication of the purity of a clay. The particles of a pure clay substance are of microscopic dimensions. Different investigators have assigned different sizes to the particles of substances present in clay, but they all agree that the size of the clay particle is less than one-hundredth of a millimeter. Hence, a clay which contains a large quantity of material the grain size of which is larger than 0.01 millimeter must necessarily contain feldspar, sand, or some other impurity of a granular nature. Some impurities of clay, however, such as iron oxide, calcium carbonate, or even very fine silica, may occur in grain size smaller than the maximum size of the clay particle. Under this condition, the mechanical separation of the clay according to texture would classify these impurities as clay.

The texture of a clay determines to some extent the class of ware which may be made from it. A coarse-textured clay is best suited to the manufacture of that class of ware in which a rough or coarse texture is desired, such as tapestry, or rough-texture brick, earthenware, etc., or in which the surface texture is not of importance, as in the case of common brick and partition tile. Other classes of ware, such as stoneware, crockery, the better grades of earthenware, smooth-texture face brick, etc., demand a fine-grained or close-textured clay. A fine-textured clay may be used in the manufacture of coarse-textured ware either by mixing a coarse material with it or by roughening the surface of the ware after it has been formed. So, other things being equal, a fine-grained clay has a wider range of uses that has a coarse-textured one.

Aside from the appearance of the product, the texture has a very decided influence on the plasticity, shrinkage, porosity, fusibility, etc. Fine-textured clays are generally more plastic than the coarser ones, due largely to the fact that the finer ones contain a larger amount of true clay substance; but it is also a well-known fact that non-plastic materials, such as silica, may develop a slight degree of plasticity when ground extremely fine. It is thought that the very small particles produced by such fine grinding have enough surface contact with each other that the force of molecular attraction comes into play. This force gives the mass a slight bonding

power, which explains the slight plasticity which is developed. The plasticity due to texture alone, however, is extremely small, and cannot account for the plasticity of fine-textured clays.

The effect of texture on the shrinkage, porosity, and fusibility of clays is purely mechanical. In a plastic clay mass the coarse particles will be distributed uniformly throughout the mass, and will be separated from each other by water and the smaller clay particles. As the drying of the mass proceeds, all the particles will be drawn closer and closer together, and a shrinkage in volume will take place. If the clay is of a coarse texture and contains many particles that are relatively large, these particles will be drawn into contact with each other soon after the drying operation has started. They then form a mechanical frame or skeleton structure for the mass, which prevents a further apparent shrinkage of the clay volume. Further shrinkage may take place within the clay mass, but this does not affect the external volume of the ware. It does make itself evident, however, by producing a more open and porous product.

Hence, a coarse clay will have relatively low drying shrinkage and will be rather open and porous. Conversely, a fine-textured clay will ordinarily have a high drying shrinkage and will form a dense mass of low porosity.

Color

Raw clay may have a wide variety of colors and shades, ranging from white to black or from red to blue, but the raw color is a poor indication of the color which the clay will have when burned. Pure clay, which is seldom found in nature, is pure white. The colors possessed by natural clays are due to impurities, the most important of which are the compounds of iron. The color of the raw material may be materially affected by the interaction of the various impurities during the burning process.

The burned color can be determined only by making a burning trial with the clay in question, and is of importance in deciding the type of product for which the clay is adapted. A clay that burns to a red color can only be used in the manufacture of red brick, red earthenware, hollow tile, and like products. With the possible exception of "flashing" the ware and obtaining variegated shades ranging from blue to black, there is very little possibility

of controlling the color of a red-burning clay by the addition of other coloring materials. Almost any color or combination may be obtained, however, with a clay that burns to a white or light buff shade. One brick company in Arkansas manufactures 127 different shades of face brick from their clay.

The principal factors governing the color of fired ceramic ware have already been discussed under the heading of the different clay components which affect the color, and will not be further discussed at this point. It is sufficient to note that the color obtained in the finished product may exert considerable influence upon the market value of the product.

Specific Gravity

The specific gravity of a material is measured by its weight per unit of volume relative to the weight of the same volume of some standard, usually water. The determination of this value is of importance to the manufacturer of high-grade china and porcelain, as a means of determining the purity of the raw materials used and also as a basis for controlling the time and temperature of heat treatment required. It has very little or no significance to the manufacturer of the lower grades of clay products, such as brick, tile, stoneware, pottery, etc.

CHAPTER III

CLAY-WORKING METHODS

Methods of Winning the Clay

There are many different methods used in the excavation of clay deposits. In pits where there are a number of strata of different-grade clays, and it is desirable to keep each grade separate, the excavation is done by pick and shovel. In such cases the deposit is usually worked in small pits about fifteen feet square. The depth of the pit depends, of course, on the depth of the stratum being worked. In this way each successive stratum is removed separately. This method of excavation is expensive and is advisable only when each stratum is high-grade clay but all strata are not suitable for the same purpose and must be kept separate from each other.

The hydraulic method of excavation can be used advantageously if the clay is easily slaked and it is desired to wash it before it is ready for working. This method consists in directing a stream of water under high pressure against the face of the deposit or into shafts drilled into the deposit. The water, together with the high pressure or force, serve to disintegrate the clay and it is carried off as suspension in the water. The suspended material is then conducted through a long series of troughs, where the impurities are allowed to settle out. It is then collected in large vats, concentrated, filtered, pressed, and dried. The washed clay is then ready for the market or for working. This method has never been used extensively, and, with the exception of a few instances where the overburden has been removed hydraulically, it has been used only in the excavation of high-grade porcelain and china clays.

In some districts where a very hard and tough shale is used for manufacture, a machine known as a shale planer is used for the excavation. This machine takes a vertical cut from the face of the deposit from bottom to top. It consists of a framework which stands as high as it is desired to make the cut. The framework carries one or more endless chains to which are attached a series of cutting knives. As the chain is pulled up or down the face of the deposit, the knives take off a thin cut. The loosened material is dumped into a hopper and loaded into mine cars.

The shale planer does away with the necessity of explosives, and obtains the material in a much finer state than can be gotten either by hand or by power shovel. This is decidedly advantageous, since it reduces the power necessary for driving the grinding machinery. The shale planer also gives a much more uniform mixture of the clay as it comes from the pit. While it has not been used extensively except for the excavation of hard and tough shales, it could be used advantageously wherever it is desired to mix the clay uniformly from top to bottom, and when the depth of the clay deposit and the plant capacity is sufficient to make its use economical.

If the clay is extremely hard, as in the case of flint clays and very hard shales, quarry methods are used in their excavation. Operations of this sort follow the general methods of quarrying, and require the use of explosives and power shovel work.

Ordinary mining methods, with the use of shafts, tunnels, and drifts, involve the use of picks and shovels assisted by explosives, and are employed for the excavation of clays only when the amount of overburden is too great to be stripped economically and where the clay is of such high grade as to justify the expense. Clays of slightly lower grade are sometimes mined by this method when they are found associated with coal or other minerals which are being mined and the same entries can be used to obtain the clay. It is reported that at one time clay was mined to a small extent in some of the lignite mines near Rockdale, but this practice has been discontinued.

None of the above methods are known to be in use at present within the State of Texas.

There are a few plants of small capacity, whose clay deposits are relatively shallow banks of soft loamy or silty clay, where the pick-and-shovel method of excavation is used. Excavations of this sort are usually made by digging out the face of the bank and allowing the loosened material to fall to the bottom of the pit. It is then loaded into horse-drawn wagons or carts by hand and hauled to the storage shed. This is one of the most expensive methods of excavation, and can be used only when the plant capacity is so small that mechanical methods are not economical.

There are a number of excavation methods which may be classed together and which may be considered as a gradation between hand excavation and mechanical means of winning the clay. The first step in this transition is the use of horse-drawn, or, in the case of slightly larger capacity, tractor-drawn shovel scrapers. For such excavations the pit is usually a bowl-shaped depression. The clay is scraped off of the surface by the shovels and carried by them to a trap through which the clay is dumped into a car or wagon. This method can be employed only when the clay to be worked is a loose, friable material. When it is desirable to work a firm clay by the scraper method, plows must be employed to loosen the clay before the scrapers can be used.

In this method, in addition to the common types of drag shovels, there is employed a type known as the clay-gatherer or harvester, which consists of a large drum mounted between two wheels. As the machine is pulled forward, scrapers cut a thin layer off the surface of the earth, hoist it, and dump it into the drum.

There are a number of disadvantages to the scraper or harvester method of excavation. While it is an improvement on the pick-and-shovel method, it is not usually economical for large capacity. The pit cannot be worked during wet weather, and, if the plant is to run continuously, enough clay must be kept in storage to supply the plant through periods of bad weather. But the principal objection is that the clay is not properly mixed. This objection, of course, does not hold if the deposit is perfectly uniform; but if the deposit is made up, as most clay deposits are, of several strata of slightly different clays, more of one stratum will be delivered to the plant at one time than at another. If these several clays have slightly different physical characteristics, there will be much trouble introduced through variations in the drying and burning properties of the ware.

The drag-line method of excavation is known to be used by at least one plant in the State. This method consists essentially of a three-drum hoisting engine, a system of cables, and a scraper. The scraper moves along a cable which spans the portion of the deposit to be worked, and is supported by two timber frames, one at the hoisting engine and the other, which may be moved from time to time, at the opposite end of the drag line. The cables from all

FIG. 4. CLAY EXCAVATION BY HORSE-DRAWN SHOVEL SCRAPERS IN THE PIT OF A DALLAS, TEXAS, BRICK PLANT

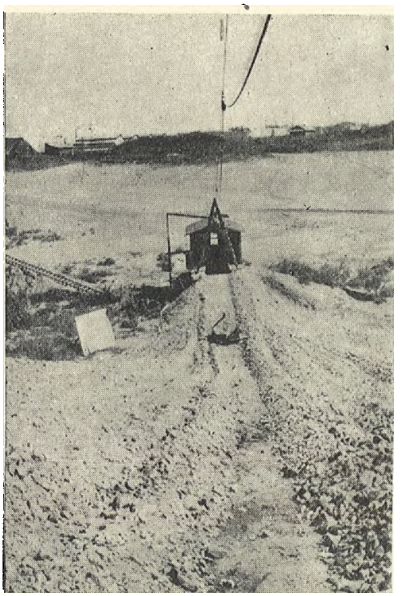

FIG. 5. CLAY EXCAVATION BY DRAG-LINE METHOD AT BRICK PLANT AT FERRIS, TEXAS

three drums of the engine are attached to the scraper, one serving to pull the scraper with its load toward the hoisting engine; another, connected through a sheave at the opposite end, draws the empty scraper back for a new load, and the third is used to tip the scraper so as to take up or discharge a load.

The drag-line method can be used for either surface excavation or for operation along the face of a cut. However, it is best adapted to the excavation of deposits which are peculiarly situated or are more or less inaccessible. When this method is used for surface excavation it has the same disadvantage as any surface operation, namely, that clay of a uniform grade cannot be furnished to the plant unless the material of the deposit is naturally uniform. If the method is used on the face of a cut, this objection is overcome to some extent, as approximately proportional parts of the various strata are taken in each load and mixed to some extent. Under this special condition, clay of a more or less uniform composition may be delivered to the plant. When the right conditions prevail in the deposit, and the drag line is handled properly, it is about as economical as any other type of excavating machinery.

The most popular excavating device for large-scale operation in this State is the power shovel. There are a number of different types of power shovels, differing chiefly in their source of power and method of traction. The power may be either electric motor, internal combustion engine, or steam engine. The trucks on which many shovels are mounted are built to run on rails, the smaller ones on narrow-gauge and the larger ones on standard-gauge track. Other trucks are mounted on broad-tired wheels similar to tractor wheels, thus doing away with the necessity of laying track whenever the shovel is moved. Trucks mounted on caterpillar tread seem to be well adapted to clay-pit work, but are not in general use in this section.

Steam-power shovels, mounted on standard-gauge track, are by far the most common type of shovel in use in Texas wherever plant capacities are sufficiently large to permit of their use. The capacity of steam shovels depends both upon the size of the dipper and the nature of the clay. Generally speaking, a 25-ton shovel will move from 200 to 225 tons of clay per day; a 35-ton shovel, 260 to 325 tons; a 45-ton shovel, 300 to 600 tons; and a 60-ton

shovel, 400 to 1,000 tons. In some cases the small machines can be operated economically in pits having a total output of not less than 75 tons of clay per day, but the larger sizes require a daily output of at least 200 tons.

With the possible exception of the shale planer previously mentioned, the power shovel is the most economical method of clay excavation for large-scale production. There are a number of advantages to be gained by this use of the power shovel. While long periods of bad weather will hamper operations in the pit, or even stop them entirely, delays from this cause are not nearly so apt to occur as in the case of the other methods described. Since the shovel takes a cut straight up the face of the clay bank, the clay will be more thoroughly mixed and a more uniform grade will be delivered to the plant. The height of the economical working face varies according to the size of the shovel used, but the highest face worked by a single shovel does not exceed twenty feet. If the deposit has a greater depth, it must be worked in benches or shelves. The shale planer has an advantage in this respect in that it can work economically a face of almost any height.

Methods of Transportation

Probably the most primitive method of transporting the clay from the pit to the plant is by wagon or two-wheeled cart. This method is still in use today and is the common means of transportation in plants of small capacity where manual labor is also employed for excavating the clay. It is the most costly method when figured on the basis of cost per ton, but is the most economical for small production and short hauls.

When the pit is on about the same level with the plant, and is in close proximity, the clay may be excavated by drag shovels or scrapers, and carried by them directly to the storage pile. Clay pits are not usually so well located, and the plant capacities may be such as to make a separate method of transportation necessary. In such cases a trap is built near the center of the pit and the scrapers dump their loads through it into the wagon or car, which is then hauled to the storage shed. When cars are used, the storage shed may be built with an overhead track. The loaded cars are drawn up on this track and the clay is dumped onto the piles below.

When the pit is being worked close to the plant, the car may be drawn directly from the trap to the overhead track by a hoisting machine, dumped, and returned to the trap by gravity. But when the distances or the lay of the land do not permit such a procedure, a relay of cars must be used, and they must be hauled to the storage shed and back again to the trap. For short hauls horses or mules may be employed economically, but when the distance exceeds one thousand feet some form of mechanical haulage usually proves

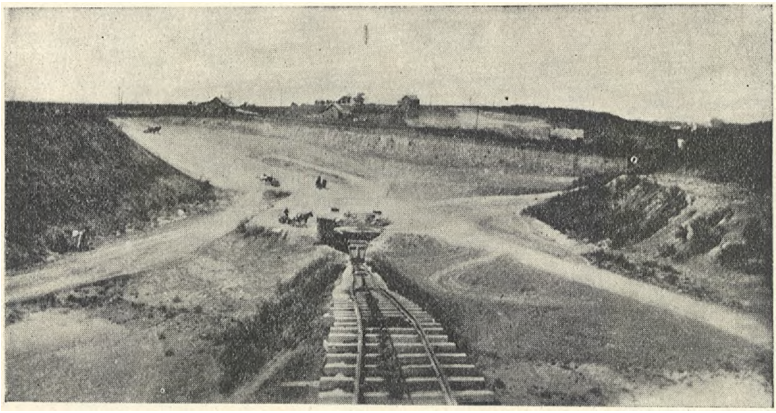

FIG. 6. LOADED CARS BEING DRAWN UP INCLINE FROM CLAY PIT TO STORAGE SHED AT A FERRIS, TEXAS, BRICK PLANT

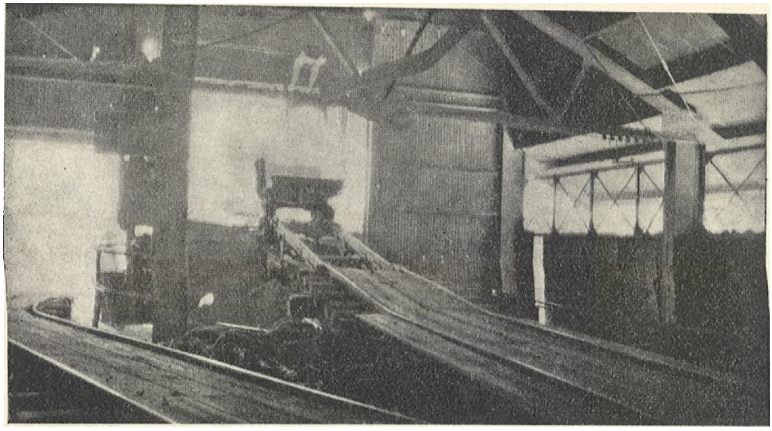

FIG. 7. CARS ENTERING CLAY STORAGE SHED AT BRICK PLANT AT FERRIS, TEXAS

best. Gasoline locomotives are known to be used to some extent in the State for this purpose, and seem to give good service.

When the clay pit is located some distance from the plant, and the capacity is such as to warrant the investment, a small saddle-tank steam locomotive is probably the most economical. The capacity of the plant must be sufficient, however, to keep the locomotive going constantly and to haul a number of cars each trip.

Aerial tramways are used for clay transportation when conditions are such as to make them practicable. One plant in the State uses such an installation to carry clay from their pit to the plant, which is located on the opposite bank of a river, the tramway in this case being much cheaper than a bridge which otherwise would have to be built. This system is reported to give very good service at a relatively low operating cost.

Another plant, now idle, installed such a tramway to transport clay over a distance of about four miles. The cost of the installation was considerable (said to be about $40,000), and the management reported that the system never gave satisfactory service. The failure of this system, which was operated only a short time, may have been due either to structural features or to operating conditions, as tramways are known to give satisfactory results over long distances. The gypsum plant of the Pacific Portland Cement Company, located at Gerlach, Nevada, transports its gypsum over an aerial tramway which is five miles in length. Due to the ruggedness of the country, one of the spans is slightly over 2,000 feet in length. This system is capable of delivering 100 tons of crushed rock gypsum per hour and is driven by a 15-horsepower electric motor. The power requirement would be much greater, however, were it not for the drop of 850 feet from the loading end to the mill.

The initial cost of an aerial tramway system is very large, and unless the topography of the country is such as to make such a system necessary, either narrow or standard-gauge track and locomotive transportation usually proves more economical.

Clay Storage and Preparation for Disintegration

The type of storage and the method of preparation for grinding and tempering depends largely upon the nature of the clay and

the type of product to be manufactured. Most of the Texas plants have a large shed, open on all sides, but roofed over in order to protect the clay during wet weather. The cars loaded with clay from the pit are hauled up an incline onto an overhead track which runs just under the roof of the shed. Their loads are dumped from this track at whatever point desired, so as to form a pile which spreads out almost to the outer limits of the roofed area, the pile building up to a sharp ridge in the center and extending almost up to the overhead track. If there is no preliminary preparation necessary, the clay is gathered from this pile by wheelbarrow, scraper, or belt conveyor, and carried directly to the grinding machinery.

Sometimes it is desirable to weather the clay before it starts through the manufacturing process. In such cases no storage shed is employed. The clay is spread out over a flat surface to a depth of two or three feet, and is exposed to frost, wind, rain, and sun for several months, and sometimes even years. The weathering process results in a slow but thorough disintegration of the clay. If there are any iron nodules present they will rust, and can then be more easily seen and discarded. This process tends to leach out any soluble salts that may be present, but if iron pyrites is present its oxidation will produce soluble salts, and in this case, if sufficient time is not allowed for the leaching out of these salts, the weathering process may result in an increase rather than a decrease in the soluble salt content.

Frequently the clay is so damp when mined that it will pack and choke the grinding machinery. Usually the storage pile can be worked so that no clay is taken until it has been in storage long enough to have air-dried sufficiently to overcome this difficulty. However, it is sometimes desirable to employ some further method of drying the clay. One large plant in the State employs a drying floor for this purpose. The floor of the drying shed is built of brick. Several furnaces are built under the floor at one end, and the hot flue gases from these furnaces pass through channels built in the floor to the chimney located at the opposite end. In this way the entire floor area is heated to a temperature of about 212 degrees Fahrenheit. The clay is piled on this floor and is thoroughly dried before it is sent to the grinding machines.

Some plants employ rotary driers of the common type for drying their clays.

Disintegration and Tempering

In most cases the clay is first disintegrated and then tempered, but in some cases this order is reversed or the two operations are carried on simultaneously. Many small plants whose clays slake readily in water dump the raw clay directly into pits or basins known as soaking pits. The pit varies in dimension according to the capacity of the plant. It is usually filled with enough water to render the clay plastic, and the clay is thrown in just as it comes from the deposit. The mixture is then allowed to soak over night or for whatever time may be necessary to slake the clay completely. In this way the tempering and practically complete disintegration is accomplished in one simple operation. The clay may be worked immediately as it comes from the soaking pit, but it is usually best to put it through a pug-mill or some form of mixing machine, where it is further disintegrated and thoroughly mixed so that it will be more uniform in texture.

The ring type of soaking pit is an improved form of the same device. This is a circular pit about 20 to 25 feet in diameter and about 3 feet deep. It is usually lined with boards or brick. In the center of the pit is a vertical shaft which carries a horizontal arm that reaches to the edge of the pit. This arm serves as an axle for an iron wheel which is about six feet in diameter and which is so geared that as the horizontal arm swings around the pit the wheel travels back and forth from the center to the circumference, describing a spiral path through the mass of clay and water. In this way the clay is more thoroughly disintegrated and mixed in a shorter time than is possible in a soaking pit.

In pottery and whiteware plants blungers, ball mills, and slip agitators are much used in disintegrating and preparing the clay. All of these machines are used for wet grinding. The blunger is a tank usually 8 to 10 feet in diameter and about 7 feet deep. The latest types have a cast-iron shell lined with vitrified brick. The agitating mechanism is either of steel or wood. The raw materials are thoroughly ground before they are mixed in the blunger, and while a further disintegration is accomplished, it is used primarily

to mix thoroughly the various ingredients and form a homogeneous suspension of the solids in the water. The blunged material is then screened and passed over magnets to remove any iron particles that may be present. It is then collected in an agitator which is similar in construction to the blunger but which is employed primarily to keep the slip agitated so that the heavier particles will not settle until it can be pumped to the filter press.

Ball mills are essentially hollow cylinders which rotate upon a horizontal axis, and are employed when extremely fine grinding or very intimate mixing of the ingredients is necessary. The cylinder is lined with porcelain and is charged about one-third full with porcelain balls or water-worn Iceland flint pebbles of graded sizes. The mixture to be ground is placed in the mill with the grinding balls. As the cylinder is rotated, the balls roll and slide over each other, and the material is ground and thoroughly mixed. This form of grinding is usually employed on glaze mixtures, and may be used on very fine grades of body mixes.

In general, especially in the heavy clay-deposits industry, the clay is first crushed and thoroughly disintegrated before it is tempered and molded. If the clay is an extremely hard shale or flint clay, it must first be crushed to a fairly uniform size of small lumps before it can be finely ground. This preliminary crushing is accomplished in gyratory crushers, jaw crushers, and roll-hammer and swing-hammer pulverizers of the common types in use in all crushing operations. Gyratory crushers are built in sizes having capacities ranging from 2 to 1,300 tons of crushed clay per hour, and the power required ranges from 3 to 300 horsepower. Jaw-crusher capacities vary from one-half ton to 600 tons per hour, with power requirements of 5 to 250 horsepower. Roll-hammer and swing-hammer crushers have somewhat smaller unit sizes, capacities ranging from 1 to 50 tons per hour, and power ranging from 15 to 100 horsepower.

Roll crushers of a number of different forms are employed in the initial crushing of clays and shales. Single-roll, two-roll, and compound-roll crushers can all be used. A roll crusher in which the rolls are faced with a winding thread is designed to handle clays containing objectionable material in the form of hard rocks and nodules. The hard pieces are carried along by the threads

instead of passing through the rolls, and are rejected at the ends of the rolls.

A type of machine known as the disintegrator is used to some extent to pulverize shales and clays. It consists of several cages which are formed by bars of iron. These cages revolve concentrically, each succeeding one revolving in a direction opposite to that of the adjacent one. The material is fed into the inner cage and is struck with great force by the bars of the cage. As the material becomes fine enough to pass between the bars of the first cage, it is thrown out by centrifugal force and is in turn struck by the bars of the next cage. In this way it becomes well pulverized by the time it passes the last cage. Machines of this type can handle either dry or damp clay. Their capacities are large, but they require a considerable amount of power. Their capacities vary from 60 to 400 tons per hour and require from 10 to 40 horsepower.

Another type of machine used for the fine grinding of clay is the Kent mill. This consists of a large metal ring about 5 feet in diameter and 10 inches wide, the concave inner surface of which serves as the grinding surface. The ring is held in position by three small wheels whose outer surfaces run on the inner surface of the ring, and are held tightly against the ring by heavy springs. The whole mechanism is contained in a cast-iron housing. One of the small wheels is power driven, and it in turn drives the large ring and the other two wheels by friction. The material to be ground is fed onto the concave surface of the large ring in front of one of the small wheels, and is subjected both to compression and friction between them. As soon as it has been ground sufficiently, it falls over the edge of the larger ring into a receiver below. This type of machine is very satisfactory for fine grinding of very hard shales and clays.

The dry pan is the most widely used type of machinery for crushing and grinding clay. It consists of a large revolving pan supported on a vertical shaft. Two heavy iron rollers, called mullers, turn on an axle, which is supported across the top of the pan, and as the pan turns they run around on the pan bottom, grinding the clay which is fed in. The portion of the pan bottom on which the mullers run is solid, and the portion out beyond this is made

up of screen plates which allow the ground clay to drop into the receiver below. Scrapers held in front of each muller carry the unground clay back onto the grinding surface. The size of dry pans is measured by the diameter of the pan; the standard sizes have 5, 7, 8, 9, and 10-foot pans. The capacity of the unit depends upon the nature and condition of the material and degree of fineness desired, but capacities ranging from 10 to 20 tons per hour can be obtained with power consumption from 27 to 50 horsepower.

If the clay is manufactured into ware by the dry-press process, it is taken directly from the grinding machinery through a screen and then to the press where the ware is formed. However, if the mud process of manufacture is used, the clay must be tempered before it goes to the molding machine. In most plants the tempering is accomplished in a machine known as the pug-mill. This consists of a hollow cylinder with a shaft running from end to end through the center. If the mill is vertical, the outer shell forms a complete cylinder, but the most popular type works in a horizontal position and the shell forms only a half cylinder on the bottom, the sides extending well up above the shaft. The shaft carries blades or knives, which are staggered and have a slight bevel so that as they cut through the material they tend to push it from one end to the other. The ground clay and water mixture is introduced at one end, and is cut, wedged, and thoroughly mixed as it moves along the cylinder to the exit.

Many common brick plants which use a loamy clay that slakes readily in water use no grinding machine whatever. The clay from the pit is fed directly into a pug-mill of the type just described, and mixed with water. The slaking action of the water, together with the cutting and stirring of the blades, mix and disintegrate the clay sufficiently for molding.

The wet pan is used to a considerable extent by pottery plants and some heavy clay-products plants for tempering the clay. The wet pan does not differ essentially from the dry pan, except that the mullers do not usually have as wide a tread and the pan bottom is solid all the way out to the rim. The wet pan has a decided advantage over the pug-mill as a tempering machine because it not only thoroughly tempers and mixes the clay, but it also continues the grinding process. On the other hand, the capacity is limited

by the fact that the process by this method is essentially a batch operation. This results in an increased power consumption, but the additional grinding is sometimes necessary to improve the working properties of the clay. Wet pans are made in the same standard sizes as are dry pans.

The chaser-mill is used to a considerable extent by pottery and stoneware plants. This is a modification of the ring pit, which has already been described, and performs the same function as the wet pan. The dimensions are nearly the same as for the wet pan, but the pan is stationary. and the material is ground and mixed by a wheel which turns on an axle which swings about within the pan, moving back and forth between the center and the circumference. Such machines are usually used without any preliminary grinding of the clay, and the time required to temper a batch ranges from two to four hours. A considerable amount of power is required and the capacities of these machines are low.

The Process and Method of Forming

In the manufacture of heavy clay products there are three types of processes in use, distinguishable by the amount of water used in tempering or the condition of the clay when ready for molding.

The soft-mud process is probably the oldest method of molding clay, and is still used in many plants. It is used primarily in the manufacture of common brick, but may be used in connection with a repress in the manufacture of face or fire brick. It has a wider range of adaptability than any other process, and has a decided advantage in that it produces a product which is more homogeneous in structure and is least affected by frost action. This process consists essentially of mixing the clay, or clay and sand, with sufficient water to make a soft mud or paste. It is then pressed into wooden molds. Since the wet clay is likely to stick to the wooden surfaces, the molds are wet and sanded each time before use. Soft-mud bricks thus usually show five sanded surfaces and one rough surface where the excess clay has been scraped off along the top of the mold.

Soft-mud products were originally molded by hand, and this method is still used in a few plants, but most plants now use a soft-mud machine for this purpose. A pug-mill is usually employed

to temper the clay, and from it the mud passes into an upright press box of either wood or iron. The molds are fed under the press box and the clay pressed into the molds by plates or plungers. As soon as they are filled, the molds are automatically pushed out and another set of molds are placed under the press. The excess clay is struck off and the bricks are dumped on a pallet to dry. When operated under favorable conditions, soft-mud machines attain capacities of about 40,000 bricks per ten-hour day.

The stiff-mud process is limited to clays of moderate plasticity, but it can be used to manufacture a greater variety of products than can the soft-mud process. Since a fairly hard clay or shale is used in this process, it is first ground in a dry pan and screened before being tempered. In tempering the clay, just enough water is added to make it stick well together. The type of tempering machine depends upon the nature of the clay and the type of product to be manufactured. In the manufacture of brick and hollow tile pug-mills are generally used for tempering.

From the pug-mill the clay is fed into an auger press. This press may be a separate machine, but usually it is a continuation of the pug-mill, and both units are contained in the same housing. It consists essentially of a continuous screw or spiral worm which gathers the clay and forces it through a short tapering cylinder toward a rectangular die. If bricks are being made, the cross-sectional opening of the die corresponds either to the end or the largest side of the brick, depending on whether the brick is to be end or side-cut. The clay issues from the die in a continuous bar having the same cross-section as the die opening. The bar slides onto a cutting table and is cut into the desired lengths. The bricks are then placed on cars or racks to be carried to the drier.

The correct construction and design of the die is one of the most important factors in a stiff-mud auger machine. The nature of the raw material will have a decided influence on the construction of the die. Some clays pass through a die very readily, whereas others offer a strong resistance. Weathered clay usually causes less die trouble than does unweathered material, and it is best to mix as large a proportion as possible of weathered material with each batch that goes to the pan. Where the proportion of weathered clay brought from the pit is small, it is sometimes advisable

to allow a certain portion of the raw clay to weather before it is used.

The fineness of the grain has a considerable effect, as coarse material will slow down the column speed and may cause the corners to drag. Finer screens and more efficient tempering may increase the capacity of the auger machine considerably.

The drying properties of the clay may materially affect the design and operation of the dies. A few clays will dry successfully even though the die is considerably unbalanced, but most clays require very exact die adjustment if the drier loss is not to be excessive. In some cases the addition of a "grog" of previously burned and ground clay, mixed with the raw clay in tempering, will lessen the drier loss.

One of the greatest troubles with auger machines is due to lamination of the product. This is caused by a differential flow of the clay mass through the die. The flow of the bar will naturally tend to follow the line of least resistance, and if the die is not properly constructed the clay will flow through one portion faster than through another. This will cause the clay to form in planes which will slide on each other and break the bond between the different segments of the ware. In drying, these segments will dry at different rates and cause the ware to crack along the planes of lamination.

If the die is too close to the auger, a similar effect will be obtained. The space between the auger and the die must be sufficient to form a reservoir from which the clay is forced evenly by the auger pressure. If this reservoir is not sufficient to equalize the auger pressure, the weave given to the clay by the motion of the auger will be transmitted to the clay column issuing from the die. In some instances this weave is so pronounced as to cause the clay column to tear up as soon as it leaves the die, but in others its effect is not apparent until after the ware is dried. A reservoir, however, that is too long will increase the friction and materially cut down the capacity of the machine.

An auger that is slightly out of center may cause laminations in the ware by producing unequal pressure over the die area.

A very thorough discussion of die troubles and their remedies may be found in a book by A. F. Greaves-Walker, entitled *Clay*

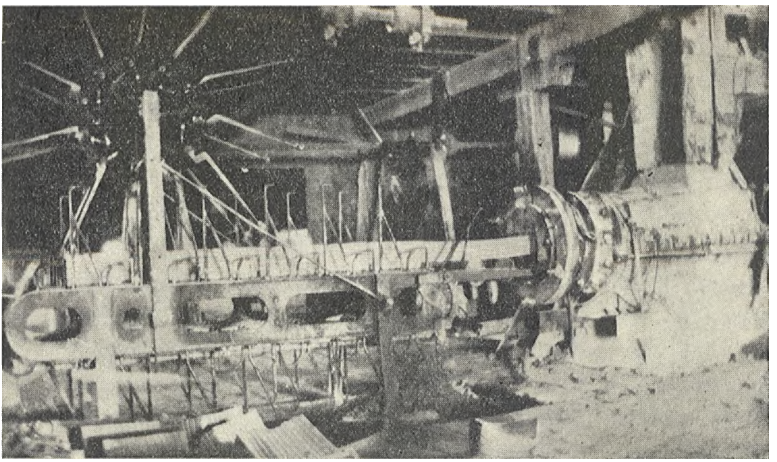

FIG. 8. STEP IN THE FORMING OF HOLLOW TILE. CLAY COLUMN COMING FROM THE AUGER MACHINE ON TO THE CUTTING TABLE AT AN ATHENS, TEXAS, PLANT

FIG. 9. UPDRAFT MUFFLE TYPE OF BEEHIVE KILN USED IN BURNING POTTERY

Plant Construction and Operation. The same can be found in *Clay Products Cyclopedia* under the heading "Dies, Factors of Operation." Both of these books are published by the *Brick and Clay Record*, or may be obtained through their office.

Very plastic clays give more die troubles through lamination thon those that are less plastic. In the manufacture of this class of clays expression rolls are sometimes used. The clay is fed to the rolls in a loose column, and the rolls compress it and pack it and force it through a die which is very similar to the die of the auger machine; but this method of feeding the clay produces a uniform pressure over the face of the die, and the tendency to differential flow and lamination is overcome. This machine is used to produce the same type of ware as the auger press. It is used to a large extent in England, but as yet is not very widely used in the United States.

The plunger machine and the steam press were the first machines used in the manufacture of stiff-mud products, and these machines are still used to a considerable extent, although their use at present is confined to the manufacture of sewer pipe, drain tile, etc. Plunger machines consist essentially of an upright mixing chamber in which the clay is tempered and mixed, and a press chamber below. The tempered clay flows down into the press chamber, where a plunger forces it through a die. This type of machine reduces the tendency of the clay to laminate by giving a uniform pressure over the face of the die, but the operation is necessarily intermittent, and the demand for larger capacities has brought on the development of the continuously operating auger machine. The formation of sewer pipe is better adapted to intermittent delivery than to continuous operation, and plunger type machines are still used for this type of ware.

The sewer pipe press consists of two cylinders connected by a piston and placed one above the other. The pressure is produced by steam upon the piston in the upper cylinder. The lower cylinder is open at the top so that the piston can be withdrawn and a new supply of tempered clay dumped into it. The piston is then forced down and the clay forced out through a die in the lower end of the cylinder. Immediately below the die, and centered perfectly with it, is a pipe table. This is supported on a vertical rod and

is counterbalanced so that it can be moved up and down. The table fits into the die so that it will hold the clay when it is forced through the die and form the flange of the pipe. It is then lowered and the pipe is pressed out. When the pipe reaches the desired length it is cut off and carried to the drying room. The pipe table is again raised to the die to form the flange of the next pipe.

All kinds of brick, drain tile, roofing tile, hollow blocks, silo blocks, terra cotta lumber, conduits, and sewer pipe can be manufactured by the stiff-mud process by using the appropriate machines and dies as described above. In the United States the auger press is almost universally used in the manufacture of all classes of ware except sewer pipe. The manufacture of the various products is mainly a question of dies. Auger presses for certain classes of ware have certain peculiarities that adapt them to the class for which they were designed, and cannot be used with satisfactory results for all classes.

As mentioned above, the clay column which issues from the die is continuous, and must be cut into the desired lengths. This is done in various ways. In the manufacture of brick, hollow tile, etc., the clay column is carried onto a cutting table. This may be operated either by hand or by power, and the operation may be controlled independently or it may work automatically in connection with the auger press. In general, the cutting mechanism consists of a series of wires stretched tightly between two arms. The top of the cutting table has narrow openings at the proper intervals to allow these wires to pass through. When the clay column has been brought to the proper position, the arms are brought down so that the wires cut through the clay bar, cutting the column into the desired lengths. The ware is then ready to be dried, unless it is to be repressed.

The repress is used quite extensively in connection with the manufacture of both soft-mud and stiff-mud products. In the case of the former, the molded ware is allowed to dry partially before it is repressed. The object in repressing is either to brand the ware or to improve its appearance by giving it smoother surfaces and sharper edges. The repress machine consists of a mold in which the piece of ware is placed and subjected to a pressure sometimes as high as 45,000 pounds, exerted through a system of

levers or cams, and transmitted through one or more plungers. Most of the use for this process is found in the manufacture of face brick, paving brick, and fire brick.

Another type of pressing machine is used in the forming of interlocking roofing tile. The auger machine is capable of producing directly the other types of tile, such as shingle, mission, and Spanish tile, but interlocking tile must be formed in a special press. The clay is formed by the auger machine into a flat ribbon of the desired thickness, which is then cut into the proper lengths on a cutting table and the pieces placed in a press which gives them the proper shape.

The dry-press process is used extensively in this State in the manufacture of face and common brick, and to some extent in the manufacture of fire brick. Since the clay is fed to the machine in a fine dust, without being tempered with water, this is commonly known as the dry-press process, although it is more accurately called the semi-dry process, in view of the fact that the clay dust generally contains from 12 to 15 per cent of moisture. The advantages of this process are that the bricks are formed with smooth faces and sharp edges, and that the drying process necessary with any mud method is eliminated. It is impossible to produce as dense a product by dry pressing as by forming it in a plastic state, and for this reason dry-press bricks usually have to be burned to a higher temperature in order to form the same bond as would be formed by a mud brick. For the same reason dry-press products usually show a granular structure.

In the dry-press process the clay must be first ground to the proper fineness and screened. Great care must be taken to keep the clay thoroughly mixed, so that the material fed to the molds is thoroughly homogeneous, otherwise the products may crack and cause excessive kiln losses. For this reason the bin above the press machine from which the molds are fed is provided with a mechanical stirrer to keep the clay well mixed.

The dry press is very similar to the repress, and consists of a heavy steel framework which carries the molds and the mechanism for driving the plungers. The molds are of hard steel and are usually heated by steam to prevent the adherence of clay. The plungers descend from above and press the loose clay into the

mold. In the later models the product is given two or three pressures to permit the escape of the air which may be entrapped between the clay particles, and which otherwise may expand and split the brick. After the last pressure is applied, the plungers are raised and the bottoms of the molds move up so that the molded bricks are brought to the level of the delivery table which stands in front of the molds. The charging box then moves forward, pushing the bricks out onto the delivery table and at the same time refilling the molds with loose clay. The charging box is connected by canvas ducts to the mixing bin above and is refilled with clay each time after the molds have been changed.

"Terra cotta" is the term applied to those clay products which are used primarily for structural decorative work. While its manufacture may be classed under the heading of heavy clay products, its production requires much more art and skill than does the manufacture of brick, hollow tile, etc. Although the color of the body itself is not of any great importance, the clays that are used in terra cotta manufacture are more carefully selected and prepared. These clays are generally of the semi-refractory type, and frequently varying proportions of different clays are mixed in order that the body may have the desired plastic and shrinkage properties.

All terra cotta is formed by hand. For small, simple designs, plaster molds are used. In this case the mold is filled to a depth of about one and one-half inches with the terra cotta body and it is pressed into all the crevices and corners by hand. The sides are then connected by partition walls of clay to strengthen the piece and the mold is set aside to allow the product to shrink so that it can be removed from the mold. After the piece has been removed from the mold any rough edges are trimmed and straightened and the piece is carried to the drying floor.

Small designs can be cast in a single mold, but large objects and special shapes are molded in sections and are joined together when placed in the building. Large, intricate designs or designs having any undercut work must be molded by hand, and a terra cotta factory must employ a number of skilled workers for this purpose.

The drying of terra cotta products, especially large designs and modeled work, has to be done very carefully, and is usually done on steam-heated floors where the temperature and humidity can be

carefully controlled. Frequently, in the case of large pieces of complex design, the drying process must be retarded. As soon as the product has been thoroughly dried it is dipped in or sprayed with a mixture of kaolin, ball clay, quartz, and feldspar, together with any other ingredients necessary to produce the desired color. This mixture forms a thin surface coating which, when the ware is burned, becomes impervious and takes on the desired color, the body beneath the coating remaining more or less porous.

In the manufacture of floor tile the selection and preparation of the raw materials must be done even more carefully. Since nearly all floor tiles are formed by the dry-press process in hand-operated machines, the clay used must be such as will not form surface cracks when pressed. They should show no tendency to warp or split on burning. Due to the nature of their use, the finished tile should be hard enough to resist abrasion and have sufficient transverse strength to resist knocks. They should also be sufficiently dense to prevent excessive absorption of water. If the facing and backing of the tile are of different compositions, they must be so adjusted to each other that the surface coating will not shiver or craze.

White-burning tiles are generally made from body mixes containing varying proportions of kaolin, ball clay, flint, and feldspar, but the body or backing of the tile may be made from mixes of buff-burning or even red-burning clays. When such colored backing is used, the facing must carry a pigment that will produce the desired color. The material is sifted into the mold and the plunger is forced down by a screw press. If the backing and facing are of different materials, the facing is first sifted into the mold to the desired depth and the backing is then sifted in on top of it and the tile is pressed.

Wall tile is manufactured in much the same manner as floor tile, but there is considerable difference in the character of the raw materials and the style of decoration. Such tile does not have to meet the requirements of resistance to abrasion and transverse strength necessary for floor tile. The body or backing is seldom burned to vitrification, but is usually burned just hard enough to resist scratching with a knife. The body is usually made of white-burning clays which may be mixed with flint or feldspar to give

the desired burning properties. The prepared body is then molded by hand presses in the same manner as floor tile, but no facing material is used. The tile thus formed is burned in a biscuit kiln. The porous burned tile is then dipped in or sprayed with a vitrifying mixture and refired in a muffle kiln to develop the glaze.

There are a number of methods used in decorating wall tile. In many cases a relief design is impressed on the face of the tile when molded. Different colored glazes and underglaze decorations are also used to a considerable extent. In some cases print work and hand painting are also used to ornament the tile.

Pottery includes a large variety of products ranging from common earthenware to the highly artistic and delicate poreclain vases. Earthenware is made from the lower grades of plastic clays and is usually red or cream colored. This type of ware is never burned to vitrification, but is very porous and can usually be scratched with a knife. It is seldom glazed, and the only kind of decoration used on it is in the form of relief designs, which are produced during the molding process.

Yellow, or Rockingham, ware is usually made of fire clay or semi-fire clay. It has a porous body which is buff colored and is covered with a transparent or yellowish glaze. This ware is used largely for culinary purposes.

Majolica and Faience are terms used rather indiscriminately to describe classes of pottery. A classification suggested by S. C. Burt[1] defines Faience as pottery in which the colored body is covered by a clear glaze, and Majolica as pottery in which the colored body is covered by an opaque enamel.

Stoneware is usually made of semi-fire clay. The ware is burned until the body is thoroughly vitrified, and usually has a bluish or cream color, but is never pure white. The surface is always glazed either with a slip clay or a composition such as will mature at the same temperature as the body. Stoneware is used for milk crocks, churns, water-coolers, chemical ware, etc.

White ware is a general term which covers a number of grades, all of which have a white or nearly white porous body and are usually covered by a glaze. The body of the ware is made up of

[1]Burt, J. Amer. Ceram. Soc., VI, p. 109, 1904.

a mixture of kaolin, ball clay, flint, feldspar, etc., in varying percentages, and the different grades differ primarily in the degree of whiteness and vitrification of the body.

Porcelain is manufactured from the same materials as white ware, but greater care is used in their selection and preparation. The proportions of the several materials are also carefully controlled so that the body of the finished product will be vitrified and translucent. There are several grades of porcelain, the chief ones differing in the fluxing materials used. Porcelain in which feldspar is used as the flux is known as spar china or hard porcelain; that in which bone ash is used is known as bone china.

The preparation of the materials for the manufacture of the common grades of pottery is very similar to that necessary in the manufacture of heavy clay products, and the technology is fairly simple. The clay may be weathered for a short period in order to mellow it and improve its plastic properties, but this is not always done. In the manufacture of earthenware such as flower pots the tempering process is reduced to a minimum. The tempered material is cut into blocks of the required size and these blocks are placed in a machine which operates on the same principle as a drill press. There is an upright casting which takes the place of the bed plate of the drill press and holds the outside mold for the pot. The core, or inside part of the mold, is attached to the end of a revolving shaft which slides vertically and can be brought down centrally into the pot mold by the operator. The block of clay, which is just sufficient to fill the space between the core and the outer mold, is placed in the mold and the core is brought down, pressing the clay out so as to fill all of the space. The formed pot is then removed from the mold and dried. This type of ware is also made in plaster molds by jiggering, which method will be described under stoneware.

In the manufacture of stoneware the tempering operation is much more thorough than for earthenware, and the tempered material is wedged or worked before being molded. This wedging is usually done by hand and is carried out for the purpose of freeing the clay from air bubbles and rendering the mass more homogeneous.

"Throwing" is one of the oldest methods of molding, and is still used by many of the smaller stoneware factories. This method can

only be used for ware that has a circular cross-section and the walls must be thick enough to hold their shape under their own weight. A lump of clay large enough to form the desired piece is placed on a horizontal revolving disc, and as this wheel revolves, the operator molds the clay into the desired shape with his hands. When the molding is finished the piece is cut from the disc by running a small wire underneath it. This method is used largely for the formation of churns, jugs, jars, etc.

Jiggering and jollying is a much faster method of forming ware, and does not require the skill that is necessary for throwing, and for these reasons has largely superseded the older method in the larger factories. The jolly consists of a revolving shaft which stands vertically and which carries a hollow or bowl-shaped head. Above this head is a template arm which can be pulled down to a regulated stop position. In forming ware, a plaster mold, the outside of which is shaped so that it forms a snug fit, is placed in the hollow head. The interior of this mold has the same shape as the outside of the ware to be formed. A lump of clay which has been tempered to a soft-mud consistency is placed in the mold, and the revolving movement tends to spread it out over the inside surface. The template is shaped so that it forms the inside of the piece, and is so adjusted as to give the proper wall thickness. The template, mold, and revolving head must all be accurately centered so that the walls will be formed of a uniform thickness. Any excess clay is scraped off and collected by the template. As soon as the ware has been formed, the mold is removed and an empty mold placed in the jolly-head. The mold containing the newly formed ware is set aside until the piece has dried sufficiently to be removed.

Although a jolly machine has been devised which successfully forms objects having an elliptical cross-section, its use is still confined largely to the manufacture of ware having a fairly large opening at the top and a circular cross-section such as cups, jars, flower pots, milk crocks, etc.

A modification of the jolly is used in the manufacture of plates, saucers, etc. The machine itself does not differ essentially, but the mold is so shaped as to form the inner surface of the ware while the template forms the outer surface.

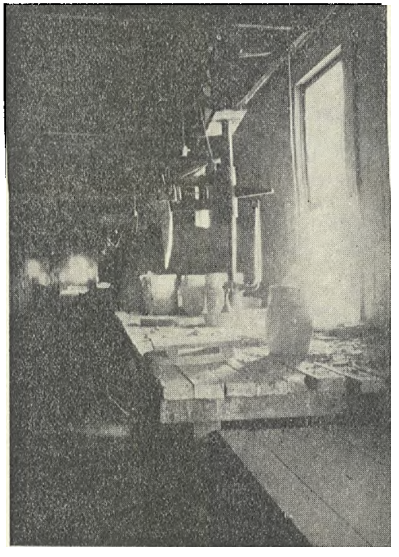

FIG. 10. JIGGER AND MOLD IN POTTERY PLANT AT FORT WORTH, TEXAS

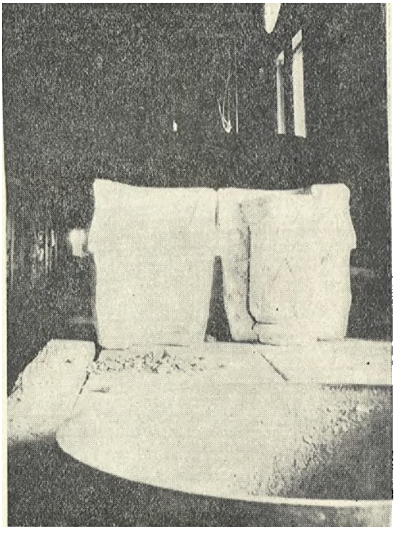

FIG. 11. PLASTER MOLD FOR CASTING, AT POTTERY PLANT AT FORT WORTH

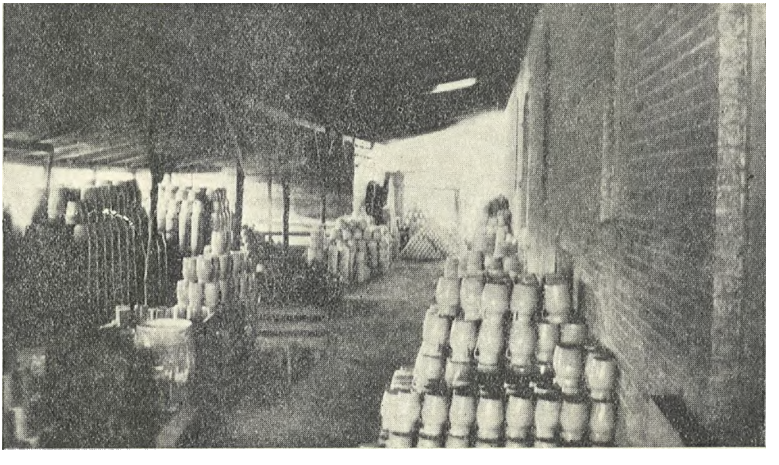

FIG. 12. FINISHED POTTERY WARE IN WAREHOUSE AT ATHENS, TEXAS

In the manufacture of white ware and porcelain, carefully selected and prepared materials are essential, but the successful manufacture of this class of ware also requires a high degree of skill and intelligence. As stated above, a number of different materials are compounded in the manufacture of white ware and porcelain in order that the bodies may have the desired physical properties such as plasticity, shrinkage, etc. The materials are selected with a view to their white-buring qualities, and in addition they are carefully washed and prepared in order to remove any iron or other coarse and heavy impurities.

White ware bodies usually contain kaolin, ball clay, flint, and feldspar. Other materials may be added to produce effects which may be desired in particular cases, but in general the above named substances are the basic ingredients. Kaolin is used because of its whitness and refractoriness, but its low plasticity must be counteracted by the addition of a small amount of highly plastic ball clay. Ground quartz or flint is added to reduce shrinkage, and feldspar or bone ash acts as a flux to produce the proper degree of vitrification at the desired temperature.

White ware is formed by several different processes. The jolly and jigger are used extensively in the forming of cups, plates, saucers, and similar articles. Oval or elliptical ware may be made on a special form of jolly, but a large amount is still made by pressing. The molds for pressed ware are made in two or more sections. A layer of clay, a little firmer than soft mud, is placed in each section and firmly pressed by hand into all corners and crevices. The sections are then put together, the different layers welded together, and the mold set aside until the clay has dried sufficiently to be removed. Any rough edges or corners are then retouched and the drying is completed.

The use of the casting process for white ware and porcelain has increased considerably during the last few years. In forming ware by this process, the clay is made up into a thin "slip" about the consistency of cream. This slip is poured into a plaster mold and the absorption of the water by the mold causes a thin layer of clay to be deposited on the inner surface. The slip is allowed to stand until this layer has attained the desired thickness, and the excess of slip is then poured out. In a few hours the ware will have dried

sufficiently to be removed from the mold, and it is then carried to the drying room. Even though this is a much faster process than pressing, there is a disadvantage in the fact that since an alkaline salt must generally be added in order to get a more liquid slip with less water, this salt usually causes the ware to become brittle. The cheapness of the method, however, more than offsets this disadvantage, and the casting method is being used to a large extent in the formation of dishes, sanitary ware, and porcelain articles. It is practically the only process by which articles having very thin walls may be made.

White ware and porcelain must be fired at least twice, and if the piece is decorated by overglaze work it must be fired three times. As soon as the ware has been air dried it is fired in the biscuit kiln to develop the body. The biscuit ware is then coated with the glaze mixture and fired in the glost kiln to develop the glaze.

Since white ware bodies are not vitrified, the biscuit fire reaches the highest temperature, the kiln being carried to about cone 8 or 9 (1,290 to 1,310 degrees Centigrade). This temperature develops the body to the desired density, but leaves it porous enough to absorb the slip glaze. The glazed ware is then refired in the glost kiln to about cone 2 to 6 (1,170 to 1,250 degrees) to develop the glaze.

The glazes used on both white ware and porcelain are artificial in character and are compounded of acids and bases in such proportions that they melt to a glass at the temperature of the glost kiln. These glazes must be carefully mixed and prepared so that they will agree with the body in shrinkage and in heat expansion, otherwise certain defects will result, such as crazing, shivering, peeling, etc.

Since the body of porcelain ware is vitrified, it cannot be fully developed before the glaze is put on. Consequently, the biscuit fire for porcelain articles is much lower than the glost fire, and usually reaches only about cone 2 (1,170 degrees Centigrade). At this temperature the body is sufficiently well developed to withstand handling and is still porous enough to be glazed. After glazing the ware is refired in the glost kiln to about cones 11 and 13 (1,350 to 1,390 degrees Centigrade). at which temperature both the glaze and the body are developed.

Drying Clay Ware

The problem of drying clay ware is one of the most difficult in the clay-working industry. An accurate classification of clays according to drying qualities is practically impossible, since their drying behavior varies so widely and the behavior of a certain clay when used for one type of ware is not necessarily the same as when it is used for some other type.

A rough classification of clays according to drying properties may be made as follows:

A. Safe drying clays—those clays which may be dried in twenty-four hours or less under the following conditions:

(1) Starting with an initial high temperature and rapid drying condition.[2]

(2) Starting with an initial low temperature and rapid drying conditions, and increasing the temperature until the ware is dry.

(3) Starting with an initial low temperature and slow drying conditions, and increasing both until the ware is dry.

B. Tender drying clays—those clays which require more than twenty-four hours to dry—all starting with a low temperature and gradually increasing it until the ware is dry:

(1) Starting under slow drying conditions.

(2) Starting with a saturated but moving atmosphere and gradually increasing the rate of drying.

(3) Starting with a stagnant saturated atmosphere and heating up slowly before advancing into a moving dry atmosphere.

C. Clays which cannot be dried under any conditions.

This is, of course, only a rough classification which is intended to show the difficulties which may be met in the drying of clay wares. It may not be possible to place certain clays under any one of these heads. In such cases a combination of two or more of the methods outlined may be found necessary to dry the ware satisfactorily. Again, the same clay manufactured into different types of ware will fall under different headings.

The water which is present in clays has been classified in several ways. One classification divides it into shrinkage water, pore water,

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[2]Drying conditions are "slow" or "rapid" accordingly as the atmosphere in which the ware is dried is relatively more or less humid.

hygroscopic water, and combined water; another, as water of dilution, water of plasticity, hygroscopic water, and combined or chemical water. A more simple classification is as mechanical or free water, hygroscopic water, and chemically combined water. A classification which is simple and at the same time more expressive of the conditions met in practice is obtained by combination of the above as follows:

(1) Free water.
(2) Water of plasticity.
(3) Hygroscopic water.
(4) Chemically combined water.

Free water is the water present beyond the amount required to render the clay plastic. This water can be removed by filtration or settling.

The water of plasticity is that portion which is necessary to render the clay mass mobile so that it can be molded. It fills the pore spaces in the clay and surrounds the grains so that they may slide over each other readily. This water may be removed by evaporation at temperatures which do not have to exceed 100 degrees Centigrade, but cannot be removed mechanically, as by filtration. Water of plasticity is divided into two parts: shrinkage water and pore water. Shrinkage water is that portion during the evaporation of which the dry shrinkage of the ware takes place. Pore water fills the pores and remains after the shrinkage has ceased and until the clay has reached a constant weight at a temperature of 110 degrees Centigrade.

When a clay mass is set aside to dry, evaporation takes place at the surface, and as the evaporation proceeds more water is brought to the surface by capillarity. This action decreases the volume occupied by the water in the mass, and the clay grains, which are drawn together by the attractive force which exists between the colloidal particles, rearrange themselves into a more compact mass and occupy the space originally occupied by the water. This rearranging of the clay grains produces a shrinkage of the mass, and the water evaporated during this process is called the shrinkage water.

As the drying proceeds the clay grains become more and more compact, until finally no more shrinkage is possible. An appreciable amount of water which fills the remaining interstitial space is, however, still present in the clay. Capillarity no longer plays an appreciable part in the drying process, but air must enter the clay mass through the pores and evaporate the water directly from the surface of the grains. This part of the water of plasticity is called the pore water.

After all the water of plasticity has been expelled, the ware is said to be "bone dry," but it still contains a small amount of water held tenaciously, due to the hygroscopic properties of the clay particles. This water is not expelled until the ware has been heated well above the boiling point of water. This portion of the moisture content is known as hygroscopic water and is expelled through the temperature range from 200 to 400 degrees Centigrade.

There still remains in the clay that water which is chemically combined as a part of the clay molecule. This water is not lost until a temperature of about 600 degrees Centigrade is reached, at which temperature the clay molecule begins to decompose. After this decomposition has taken place the character of the molecule is completely changed and the property of plasticity is lost.

The clay worker in general is not concerned with the hygroscopic and chemical water, as these are not expelled until the ware is placed in the kiln. The hygroscopic water, however, can cause much trouble if the initial firing or "water smoking" period is not carefully handled. The water which is expelled from the ware nearest the fire box may condense on the colder ware farther on and be absorbed by it. This will cause swelling and probably cracking of the ware which absorbs the water. In extreme cases the ware may absorb enough water to become soft and plastic, and be deformed under its own weight or the weight of any ware that may be stacked above it. A good draft through the kiln during this part of the burning process is essential in order that the warming may be more uniform and that all water evaporated from the ware may be carried on to the stack before any condensation can take place.

The hygroscopic water may also cause trouble if the kiln is heated too fast, in which case the temperature within the ware may

rise so rapidly that the water will be evaporated faster than it can escape through the pores of the clay. This, of course, produces a pressure within the clay which may weaken the bond and cause faulty ware or even produce rupture immediately. Extreme cases are known to have occurred in which the violence of the rupture amounted to an explosion of the ware in the kiln.

The water of plasticity is all that is removed in the ordinary drying operation, and is the portion with which the average clay worker is most concerned. If the clay mass is open and porous, drying will proceed more or less rapidly and will not be accompanied with many difficulties. But if the clay is of a gummy nature the ware will be very dense and the pore spaces very small. Such clays give considerable trouble in drying, because the water does not rise to the surface readily nor does the air penetrate the mass to any great extent after the shrinkage water has been removed. Such clays have to be dried very slowly, and frequently the initial drying has to be done under controlled conditions. No attempt will be made here to describe all the various methods used in drying clay, but a general description of the most common form of driers will be given.

The oldest and simplest method of drying clay ware is the open yard. Originally, all ware was dried in this manner, and in primitive times it was not even burned further than by the heat of the sun. The sun-baked bricks, or adobes, are well known in the Southwest even today. The sun-drying method is still used to a large extent in the manufacture of soft-mud bricks. The bricks are laid flat on the ground and are exposed to the sun, wind, and rain. As soon as the drying has progressed sufficiently that the bricks will hold their shape when moved, they are turned up on a narrow side in order that more surface may be exposed to the weather and drying may thus be hastened. When the bricks are thoroughly air dried they are collected and stacked in a kiln for burning. Obviously, only a very robust clay will stand such treatment.

In order to provide a greater output per unit of drying space and make possible the handling of more tender clays, the rack-and-pallet system of drying has been developed. In this system there is a series of long sheds or racks, each having an individual roof to protect the ware from rain and from the direct rays of the sun.

Each rack has a number of uprights, placed at the proper intervals and equipped with cleats for holding the pallets. Six or seven bricks are placed on each pallet and the pallets are stacked one above the other in the drying racks on the cleats provided. The space between each series of racks is covered by a number of swinging doors which may be opened or closed as the weather permits. Another plan is to cover the whole drying shed with one roof, thus simplifying the construction.

With the above methods it is possible to dry ware only during the summer months, and during this time the plant has to finish enough ware to supply the demand during the rest of the year while the plant is idle. Artificial methods of drying clay ware are employed to overcome the limitations of these methods. Greater output, more continuous operation, and safe drying of large pieces of ware of complicated designs are advantages which offset the additional cost of artificial drying methods.

Artificial driers may be placed in two general classes: periodic and progressive driers. Periodic driers are those in which the ware is stationary and the temperature is varied as necessary throughout the entire drying process. Air may also be circulated through the drier, and when necessary the humidity of the circulating air may be carefully controlled. Rack and floor driers and certain types of tunnel and compartment driers belong to this class.

Progressive driers are always of either the tunnel or compartment type. The ware enters first into a region or compartment of low temperature and usually relatively high humidity, and passes by degrees into regions of higher temperatures and lower humidities. Air circulation is provided for, the air usually entering fairly dry at the high-temperature end of the drier and passing toward the low-temperature end counter-current to the movement of the ware. This air is thus cooled by the ware and rendered more humid by the water evaporated from the ware.

Driers may be heated directly by furnaces, or the circulating air may be heated and convey its heat to the ware. Drying floors or hot floors are usually about one hundred feet in length and have any desired width. They are heated by furnaces built below and at one end, the heat being distributed over the floor by flues running below it from the furnaces to the stack on the opposite end

of the floor. The ware to be dried is placed directly on the floor. Such floors cannot be heated to a uniform temperature over their entire area, but this is an advantage in plants manufacturing a variety of classes of ware, since different classes of products usually require different drying temperatures, and appropriate temperatures for all classes can usually be found on such floors. Most modern drying floors have a second slatted floor above for large ware or ware of intricate design, such ware requiring slower drying. The upper floor is heated only by convection from the lower, the temperature being therefore lower and the air carrying some moisture from the lower floor. Thus the rate of drying is much slower on such an upper floor.

The installation cost of a drying floor is low, but the operation is very inefficient. Its chief advantage is that the ware can be watched very carefully during the drying operation. It is also very successful in the drying of ware that is to be repressed after partly dry.

Tunnel and compartment driers of both the periodic and progressive type may be heated by direct-fired furnaces. In such cases the air is usually heated by being passed through the furnace, and is then circulated through the drier.

Many plants which have a large amount of exhaust steam are making a considerable saving by using it to heat their driers. Both periodic and progressive driers may be heated by exhaust steam. Hot floors heated by this medium are simply large rooms heated by coils of steam pipes arranged so that as nearly a uniform temperature as possible is maintained throughout the room.

Exhaust steam tunnel driers of the progressive type are also heated by pipe coils, but the piping is usually more concentrated at the exit or high-temperature end, and the amount of pipe surface decreases toward the end at which the ware enters. The circulation of air is also counter-current to the movement of the ware, as already described.

In heating with exhaust steam the heat is transferred to the ware both by radiation and by convection, and either form of transfer may be made to do the major part of the work as desired. A disadvantage encountered in the use of exhaust steam is the necessity of supplying live steam from the boilers to the driers during the

night or during any time when the plant is not operating at full capacity and exhaust steam is not available in sufficient quantity.

A system that is being used to a considerable extent in plants of large capacity is the utilization of waste heat from the kilns. Air is heated by being drawn through hot kilns full of finished ware and is then passed through the driers. The air is thus made to serve the double purpose of cooling the burned ware and drying the green ware. A considerable economy is effected by this system, but the initial cost of installation is considerable and the necessity of having a constant source of waste heat limits it to plants of large capacity.

Burning

The burning of the product is without question the most important part of the ceramic manufacturing process. Kilns which are faulty in design or construction or are improperly fired will nullify all the good done by any amount of care that is taken in the preparation of the clay or the forming and drying of the ware. It is not the purpose of this bulletin to give a detailed discussion of kiln design or operation, but a brief discussion of the most important kilns in use will be given for the guidance of those interested.

There are numerous types of kilns being used in the various branches of the industry, varying from temporary structures which are torn down and rebuilt for each batch of ware to patented and other permanent forms which are more or less complicated in design. In general, however, all forms may be classed under three heads, according to the direction of the draft, as folows:

1. Up-draft kilns, in which the hot gases from the fire box pass directly into the bottom of the kiln, up through the ware, and out through suitable openings in the top.

2. Down-draft kilns, in which the hot gases are first carried to the top or crown of the kiln by bag walls or flues inside the kiln, and then down through the ware to flues in the bottom which connect with the stack.

3. Horizontal-draft kilns, in which the hot gases pass directly into the body of the kiln and horizontaly through the ware to the stack at the other end.

The scove kiln is probably the oldest type used in this country. It is a temporary structure and employs the up-draft system of heating. It is used only for burning common brick, and is built largely out of the brick which are to be burned. The bricks are stacked in a large rectangular mass which runs from thirty-eight to fifty-four courses in height, according to the nature of the clay. Openings for firing, which are about one foot wide by two and one-half feet high, are spaced at intervals of about two feet across the width of the mass. These are built in when the ware is set to be burned. When the green brick has been set in place, the sides and ends are closed up by old bricks, and these walls are plastered with mud to prevent the infiltration of cold air. Small fires are then started in the openings provided, and the rate of heating is gradually increased until the kiln has attained the proper temperature for maturing the brick. This final temperature is usually judged by observing the color of the platting, or top course. Such kilns are usually set with about 300,000 green bricks, and require from ten days to two weeks to burn.

The so-called Dutch kiln is a modification of the above kiln. The side walls, a portion of the end walls, and the "Dutch oven" fire boxes are of permanent construction. The green brick are set within these walls in the same manner as in the scove kiln. The openings in the end walls are bricked up and plastered in the same way. The advantage in this type of kiln lies in the better fire box construction and a lesser amount of air filtration through the permanent walls. There is also a saving in the number of bricks which are spoiled in the scove kiln where the flames from the fire box impinge on the green bricks in the arches.

A round up-draft kiln of permanent construction is used in burning stoneware and the common grades of pottery. Such kilns are usually built with two chambers, one above the other. The lower chamber serves as combustion space, while the ware to be burned is stacked in the upper. The two chambers are separated by a fire brick floor which is perforated at intervals to permit the gases from below to pass up through the ware and out the flue in the top.

The clays used in the manufacture of stoneware and pottery are frequently very sensitive to the reducing conditions which are present at certain times in the gases from the fire box. For this reason

modern kilns are built with bag walls in the upper chamber which prevent the ware from coming in direct contact with the gases from the fire box. These walls are built to varying heights, depending on the kiln and the sensitiveness of the clay. If these walls extend only part of the way up through the ware chamber, the kiln is termed a semi-muffle kiln. Many kilns, however, have the bag walls extending all the way through the ware chamber and arching over toward the central flue at the top. Such kilns are termed muffle kilns.

Down-draft kilns may be either round or rectangular, and are of permanent construction. The hot gases from the fire boxes are deflected upward by baffles or bag walls to the crown of the kiln. Then they pass downward through the ware and into the flues through the floor, and into the stack. In this type of kiln the burning process can be better regulated and there is less loss from cracked and overburned ware. The hottest portion is at the top, and if this portion is overburned to some extent it is less liable to be crushed out of shape, since it carries the least load.

Correct design and construction of such kilns is of great importance. The natural tendency of the draft is to follow the line of least resistance, and unless the auxiliary flues are properly designed and spaced in the floor the kiln will develop hot and cold spots. Such defects may be remedied to some extent by setting the ware close in the regions of highest heat and open in the cold areas, but it is much easier to adjust the setting to a properly designed kiln than to attempt to correct the faults of a poorly designed kiln by setting the ware.

Even in kilns having a good uniform draft it is often very difficult to get the bottom courses burned hard enough. The gases are naturally hotter at the point of entrance to the kiln than at the exit, and thus in down-draft kilns the top courses of ware will always receive the highest heat. However, a properly constructed kiln which has a good draft will pull the heat much nearer the bottom and will insure a more uniform burn.

The foundations of kilns are frequently not carried to a sufficient depth. They should extend at least a few inches below the deepest flue, otherwise a shaky kiln will result, which will not give the proper length of service before it must be rebuilt. Good, deep foun-

dations will also assist in keeping the bottoms dry. Damp kiln bottoms are responsible for a great deal of poorly burned ware, and the best kilns cannot give good service unless the bottoms are kept dry. A network of drain tile under and around the kiln bottom will practically eliminate any trouble from this source. A few dollars spent on a good foundation and a dry bottom will pay dividends.

Equal distribution of the hot gases, good draft, and ease of cleaning are the chief points to be considered in the design of kiln bottoms. In order to insure a uniform burn, the draft must be equally distributed over the entire kiln area. A good draft will pull the heat down to the bottom courses and thus shorten the time required for the burning. If the flues are periodically cleaned, the kiln may be kept in operation for a much longer period of time before it will require a close-down for repairs.

Down-draft kilns are built with both open and solid bottoms. Open bottoms have a checkered construction, with many small flue opening at regular and frequent intervals. Solid bottoms have only a few larger openings. In general, open-bottom kilns give much better results than solid-bottom kilns, both in producing a lesser proportion of defective ware and in shortening the burning time.

Theoretically, shallow flues are correct, but experience has shown that large, deep flues give much better results both in draft and in cleaning. The main flue should be wide enough to admit a wheelbarrow and should be high enough for a man to work in. If a deep auxiliary flue is provided which runs at right angles to the main flue through the center of the kiln, all of the secondary flues can be given a pitch of about 45 degrees. This will enable any dirt or chips which may enter to drain into the main flue, from which they can be readily removed. Such an arrangement will enable the cleaning of the flues to be done at the same time as the kiln is being set, saving a good deal of time.

The stack is a very important detail in the construction of any kiln. A poorly constructed stack may produce poor results with an otherwise well-built kiln. There are a number of stack systems in use. Many down-draft kilns are built with several stacks in t' wall. The multiple-stack system is a cheap method of construction and might be expected to give uniform burns, since each stack is supposed to control a definite portion of the kiln. It has been

found, however, that a multiple-stack kiln is very hard to control, and unless it is watched very closely the draft in one of the stacks may reverse and actually draw cold air through it into the kiln.

Single-stack kilns usually give good results if the kiln bottom is well constructed. Single stacks are usually provided with an inner lining which is separated from the outer shell by an air space in order to protect the outer shell from expansion and contraction from temperature changes.

Frequently a centrally located stack is required to serve two or more kilns. This arrangement is intended to keep the stack hot at all times so that it will produce a good draft from kilns which are just heating up. The system gives good results with carefully designed stacks and flues and careful control, but, lacking these favorable conditions, the draft from one kiln may have a detrimental effect upon that from another, and the desired advantage may prove a disadvantage. A device which has the good points of this arrangement and overcomes the objection just mentioned provides separate stacks for each kiln, but all housed in one main outer stack. In this manner the stacks serving the hotter kilns keep the other stacks hot, without having any direct effect on the draft in the others.

The construction of kiln walls and crowns varies considerably. In general, the wall should be thick enough to withstand the strain and prevent excessive loss by radiation, but thin enough to conform to good furnace design. On the whole, a well insulated thin wall, strong enough to withstand the strains, is more desirable. The major portion of the fire box will then be thrown inside the kiln. This will cause loss of kiln space, but the saving in time, fuel, and repairs will offset this loss. Thick kiln walls which contain the major part of the fire box within the wall itself are not economical. The initial cost is greater and a large part of the heat from the fuel is used in heating the masonry, making the time of burning longer. There is also an increase in upkeep due to frequent burning out of arches as a result of the concentration of heat in and around the fire box. Of course, thick walls cut down the loss of heat by radiation, but by the use of the insulating materials now available this same result can be accomplished much more cheaply with relatively thin but well insulated walls.

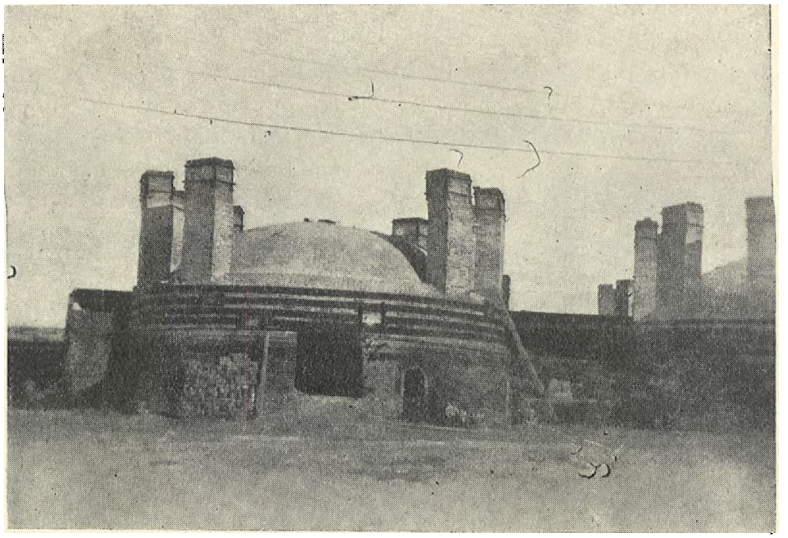

FIG. 13. MULTIPLE-STACK KILNS AT A TEXAS PLANT

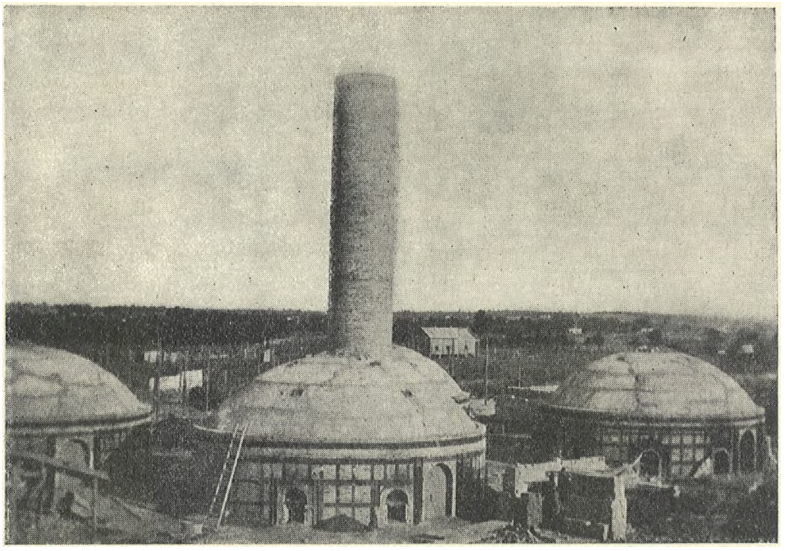

FIG. 14. CENTRAL STACK SERVING FOUR KILNS AT A BRICK PLANT NEAR AUSTIN, TEXAS

Kilns crowns should certainly be well insulated. The hottest gases naturally collect under the crown and make this the hottest part of the kiln. Since construction of thick crowns is not possible, light insulating materials must be used on this portion to prevent excessive heat loss by radiation.

Down-draft kilns are built in both round and rectangular shapes, the round shape being the most common. The circular kiln with a dome-shaped crown is frequently called the beehive kiln because of its appearance. Eight to twelve furnaces are spaced at regular intervals around the circumference of the kiln. They are either built into the circular wall or extend out from it like the Dutch-oven style of furnace. The furnace gases enter the kiln from the fire boxes and are carried upward toward the crown through short chimneys built inside the kiln. These chimneys are known as bag walls. The gases from all of the furnaces are thus collected in the crown, which forms a reservoir for them and equalizes any small differences in temperature that may occur. The gases from this reservoir then pass down through the ware and out the flue openings in the floor to the stack.

Beehive kilns vary from 18 to 30 feet in diameter and from 8 to 12 feet in height from the floor to the base or "spring" of the crown. These kilns may be set with from 30,000 to 60,000 brick. This type of kiln is used largely for the burning of sewer pipe, drain tile, pottery, face brick, etc.

Many brick plants have built rectangular down-draft kilns in order to reduce the kiln space and construction costs of beehive kilns. While the rectangular kiln is not as easily controlled within narrow limits as the round kiln, yet it will give satisfactory results on most grades of brick if properly handled. Such kilns may be built to hold 150,000 to 200,000 brick at a much lower initial construction cost and to occupy much less space than beehive kilns of similar capacity.

The rectangular kiln is similar in construction to the round form except in shape. It varies in width from 15 to 20 feet and its length may be as much as 100 feet. The fire boxes are built along the sides of the kiln and the hot gases are handled in much the same manner as with round kilns. One or more stacks may be

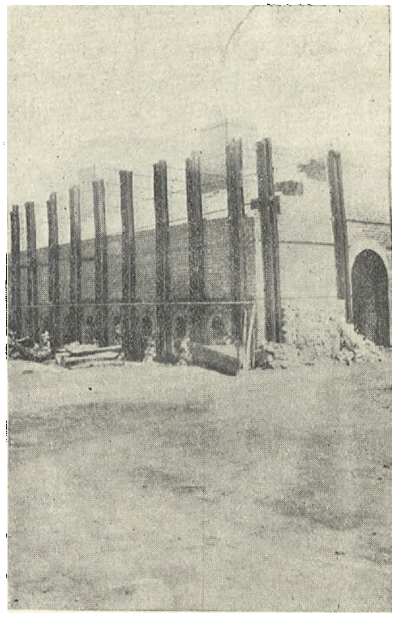

FIG. 15. RECTANGULAR DOWN-DRAFT BRICK KILN

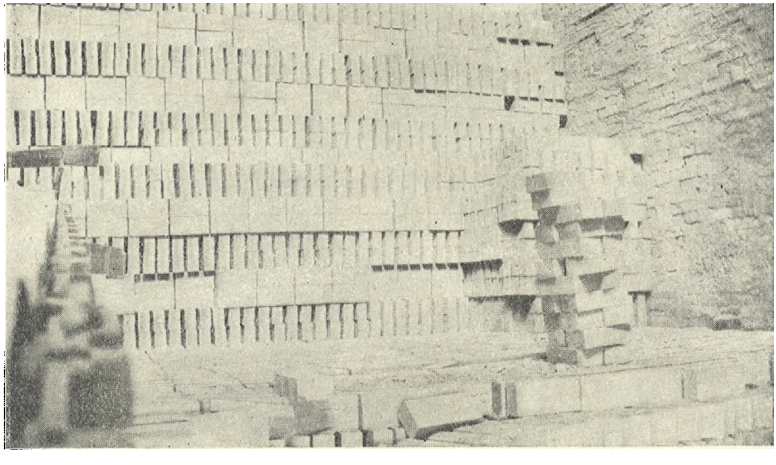

FIG. 16. METHOD OF SETTING BRICK IN AN UPDRAFT KILN IN BRICK PLANT AT DALLAS, TEXAS

provided for each kiln, but more than one rectangular kiln is never connected to the same stack.

Certain classes of clay ware such as white ware, porcelain, glazed tile, etc., which may suffer discoloration through contact with fire gases, are usually inclosed in saggers. These are small vessels in which the pieces of ware are placed and sealed in by moist clay so that the kiln gases may not come in direct contact with the ware. The saggers, with their contents, are placed in the kiln so that the kiln atmosphere may circulate freely around them to heat them well.

Saggers can only be used for burning high-grade ware, as their use materially increases the production cost. The life of the sagger itself is relatively short, and the necessity of heating the ware through the sagger walls reduces the efficiency of the kiln.

In some instances down-draft muffle kilns are built for the manufacture of white ware. These kilns consist essentially of an outer shell which is very similar to the regular down-draft kiln and an inner chamber which is as nearly hermetically sealed as possible. The hot gases pass between these two shells and the ware is placed in the inner chamber. An improved construction provides a central opening or flue through the ware chamber which collects the hot gases and conducts them to a well beneath the floor, from which they are distributed to several radial flues. This increases the area of contact of the hot gases with the muffle walls and improves the heat efficiency. Since in this sealed chamber there is little air circulation, the heat transfer is only by radiation and conduction, and it is very desirable to increase the heating surface and the time of contact of the hot gases with the surface. This lack of air circulation makes it difficult to maintain a constant temperature throughout a large space, and thereby limits the size of such kilns. An enormous amount of heat is wasted in any muffle kiln, and the use of such kilns is economically possible only when the ware produced is of the highest quality.

The continuous kiln was developed in order to utilize as much as possible of the heat which is ordinarily wasted in all types of intermittent kilns. They are built in several different forms and vary considerably in their details of construction, but all are operated on essentially the same principle. The incoming air for

combustion is drawn through the ware which has already been burned and is cooling, thus both hastening the cooling of this ware and utilizing its heat. From the combustion zone the hot gases are conducted through several compartments of ware in various stages of burning, and finally through a compartment of green ware ready to be water smoked. When finally released to the stack, the gases have cooled down to about 400 degrees Fahrenheit. Much of the heat which is lost in the stack gases of an intermittent kiln is utilized in this manner to water smoke the green ware.

As soon as the water smoking has been completed and the compartment begins to show a faint red heat, a small amount of fuel is added to assist in bringing up the temperature to complete the burn. By this time the compartment which has been receiving the highest fire will have reached the maximum temperature, and the heavy firing is advanced to the next compartment in line. This compartment is then placed on the soaking fire, and the one behind it, which has been soaking, becomes a chamber of cooling ware through which the incoming air for combustion is passed. The form of the kiln is circular or oval, the compartments facing outward around the circumference. The gases from one compartment can be passed either into the next compartment or into the flues leading to a stack in the center. The firing zone passes around the kiln in a continuous wave. The number of compartments must be sufficient to allow a few idle ones between the rear of the firing zone and the first of the preheating zone, in order to allow time for removing finished ware and resetting with green ware.

Obviously, the three stages of burning—water smoking, oxidation, and vitrification—are proceeding simultaneously. Since it is frequently necessary to hold back through certain stages of the burn, auxiliary furnaces and by-passes should be provided in order that the forward compartments may be prepared for the advancing heat. In this way the capacity of the kiln may be maintained at a maximum.

Because of the simultaneous procedure, the stack gases will be of a much more complex nature than if they resulted from only one stage of the operation. Beside the ordinary products of combustion, they will contain sulphur gases from the decomposition of sulphides and sulphates in the clay, and water evaporated and

liberated from the clay. The water content is the limiting factor in determining the temperature at which the gases shall enter the stack. This temperature must be above the dew point in order to prevent condensation. Aside from the softening effect of condensed moisture on the green ware, the dew forming in such a kiln is decidedly acid. Among the harmful effects of the condensation of an acid dew is the tendency to produce a scum or efflorescence which will spoil the appearance of the ware. The heat of the gases is used rapidly in the evaporation of the moisture in the green ware and the temperature falls rapidly as the humidity rises. Hence, the number of compartments through which the gases may be led ahead of the fire is determined by the water content.

Continuous kilns usually have one stack in the center, though it may be located at one end. Because of the low temperature at which the gases enter the stack, continuous kiln stacks must have a greater area and height in order to produce a good draft.

Continuous kilns are designed for varying capacities and for burning all classes of ware, though they are best adapted to the burning of the more common grades of brick and tile. When high-grade products are burned in such kilns they must be protected from direct contact with the gases and flying ashes. Since each type of ware, though all made from the same clay, requires different treatment in the kiln, a continuous kiln may be used only to burn the class of ware for which it is designed.

Semi-continuous kilns are built, operating on the same principle but not perfectly continuous in operation. These are usually built in a rectangular form, with the stack located at one end. They consist of a series of compartments which may be separated either by permanent walls of fire brick or by temporary partitions of paper or wood, which burn out when the buring process has advanced to a sufficient temperature. The firing is started at the end of the kiln farthest removed from the stack, and the heat is advanced slowly. The hot gases are by-passed around the remaining chambers to the stack. As soon as the gases reach a sufficient temperature they are passed into the second compartment before being by-passed to the stack. The firing is thus continued, the firing zone progressing down the kiln in a wave to the opposite end. The heat in the gases from the last few chambers is lost because they cannot

be passed on into other chambers, but go direct to the stack. Consequently, operation is not perfectly continuous and the fire must be started in the first chamber for each cycle.

The tunnel kiln is a continuous kiln operating on the countercurrent principle. The dimensions of such kilns vary from 3 to 9 feet in width, 4 to 9 feet in height, and 200 to 400 feet in length. The ware to be burned is placed on cars which are moved through the kiln by some mechanical means, usually a hydraulic piston. The bed of the car is made of refractory material, and the running gear and metal parts are insulated from the heat so far as is possible. The fuel is fed in from each side of the tunnel at a point about midway in its length. The air for combustion is drawn into the tunnel near the exit end, and passes through the burned ware, cooling the ware and being preheated thereby. The combustion takes place about midway in the kiln length, and the combustion zone varies in length according to the temperature and time of heating required to mature the ware. The combustion gases pass from the firing zone through the tunnel toward the end at which the green ware is introduced, and is then drawn off into the stack. In this way the waste heat of the exhaust gases is utilized in heating the green ware through the first stages of burning. There is a gradual rise in temperature from the entrance end to a maximum in the firing zone, and then a gradual drop as the exit end is approached. Consequently, the temperature at any particular point along the tunnel is kept fairly constant at all times.

Some tunnel kilns are of the muffle type. The air for combustion is drawn through the ware just as in the simpler type, but as it approaches the firing zone it is drawn into ducts which carry it to the combustion chamber, which is separated from the ware by refractory walls. The combustion gases then pass through the tunnel in refractory ducts and to the stack. The ware is thus never in contact with the gases, but is heated indirectly by convection and radiation from the hot surfaces. If the combustion chamber and the ducts for the combustion gases are properly arranged, the heat transfer can be aided by a circulation of the kiln atmosphere upward along the heated sides and downward through the ware in the cars. If it is desired to maintain a reducing atmosphere during any stage of the burning process, a small amount of

unburned fuel may be introduced into the tunnel at the proper point. By mechanically controlling the movement of the kiln atmosphere through the tunnel the burning process can be controlled within narrow limits.

Continuous tunnel kilns can be used for burning all classes of ware ranging from common brick and other heavy ware, which may be heated directly by the hot gases, to high grades of porcelain, chinaware, etc., which must be protected from direct contact with fiue gases by saggers or by the use of a muffle-type kiln. The fuel used may be natural or artificial gas or fuel oil. Coal cannot be fired directly in tunnel kilns economically. If coal is available for use, it may be converted into producer gas and this gas burned in the kiln.

The advantages of the tunnel kiln are: (1) Less wear and tear on the kiln as a result of the constant temperature in the various parts; (2) fuel economy as a result of the constant temperatures and the devices for heat recovery; (3) fuel economy through more efficient combustion and less radiation loss; (4) the ease of setting bricks on cars and the less danger of injuring ware by this method of setting as compared with setting a large kiln full of ware; (5) saving in cost of construction, since only the hotter portions of the kiln need be built of fire brick; and (6) ground space required is less than for any other type of kiln of similar capacity.

CHAPTER IV

CEMENTING MATERIALS

Clay is a component of Portland cement as well as of "natural" and other less common hydraulic cements. Information with regard to these cements is therefore of interest in connection with the clays of Texas, and has a place in this bulletin. While other types of cementing materials, such as gypsum plasters and lime, contain no clay as essential constituents, yet brief reference will be made to them here because of their relation to, and competition with, clay products. It is hoped that the information along these lines included here will be of help to those who are interested in the development of the lime and gypsum resources of Texas.

PLASTERS

Gypsum is hydrated calcium sulphate ($CaSO_4 \cdot 2H_2O$). When heated above a temperature of 100 degrees Centigrade it begins to lose its water of crystallization, forming a partially dehydrated product known as Plaster of Paris, which may be represented by the formula: $CaSO_4 \cdot \frac{1}{2}H_2O$. If the heating is carried above 200 degrees Centigrade the last portions of this water is removed and the anhydrous form, $CaSO_4$, is obtained. This heating destroys the crystalline form of gypsum and tends to cause it to crumble to a powder. When mixed with water, the dehydrated materials will take up water and go back to the original hydrated form, hardening or "setting" in so doing. Both the dehydration of gypsum and the reverse process which takes place in the setting of plasters are chemical phenomena of considerable complexity. A great deal of research work has been, and is still being, done on the nature of these reactions and their application to plaster technology. The following references to the literature cover the most recent work which has been done along these lines:

Peter B. Budnakov, Kolloid-Zeitung. Vol. 44, p. 242 (1928), Vol. 46, p. 95 (1928); Pit and Quarry, Vol. 16. No. 1, p. 72 (1928).

H. A. Neville and H. C. Jones, Colloid Symposium Monograph No. 6, p. 309 (1928).

D. Balereff, Kolloid-Zeitung, Vol. 48, p. 63 (1929).

F. J. Williams and F. C. Westendick. Jour. Amer. Cer. Soc., Vol. 12, p. 377 (1929).

J. A. Murray, Rock Products, Vol. 31, No. 2, p. 88 (1928).
M. L. Chassevent, Bull. soc. d'encour., 125, 789 (1926).
Robert Stumper, Zeits. anorg. allgem, Chem., 162, 127 (1927).
A. L. Parsons, Univ. of Toronto Studies, Geol. Series, Contributions to Canadian Mineralogy No. 24, p. 24 (1927).

Plaster of Paris, produced by burning pure gypsum, sets very readily. The presence of impurities, such as clay, which frequently occurs in gypsum, will tend to retard the setting as well as destroy the natural pure white color. For some purposes the pure white color and quick-setting qualities are essential, and for these purposes a pure gypsum must be used. But for many purposes these qualities are not required, and indeed the quick-setting tendency is frequently undesirable. It may even be necessary to add some substance to retard the setting action. For this purpose non-crystalline substances, such as glue, sawdust, wood fibers, packing-house tankage, etc., are added to the plaster in small quantities (seldom in excess of ¼ per cent). Plasters containing either some such added retarder, or sufficient quantities of impurities such as clay as to have the same effect, are known as "cement plasters." Wall plasters contain both a retarder and some fiber or hair to help bind the set mass together.

Completely dehydrated plasters do not set nearly so rapidly as plaster of Paris. They will set in time, however, and form a harder final product than do the quicker setting normal plasters. Such anhydrous plasters are widely used for floors. Continued heating reduces the tendency to rehydrate, and plasters in which this tendency has thus been reduced to a minimum are said to be "dead burned."

"Keene's Cement" is made by wetting dead-burned plaster with a solution of alum and then recalcining the mixture. The product of this process takes an extremely hard set. Other hard-finish plasters are made by adding borax, sodium sulphate, potassium sulphate or other salts to anhydrous calcium sulphate.

Gypsum is sometimes burned in ovens. A very uniform temperature is obtained, and thus a uniform plaster produced, but the heat efficiency of such a process is very low. By far the most common method of burning gypsum is the kettle process. The ground gypsum is heated in an iron kettle which holds from seven to twelve tons of the raw material. The fire box is immediately

below, the flames impinging directly upon the bottom of the kettle, and the hot gases also coming up around the sides to transmit more heat to the contents. A base built of brick or stone masonry supports the kettle and incloses both it and the fire box. The operating floor is on a level with or slightly above the upper rim of the kettle, the kettle and fire box, together with fuel storage and provisions for draining off the calcined plaster, being below this floor.

The gypsum is kept constantly stirred by a set of paddles on a vertical shaft. As the material is heated up, the mechanically held water begins to evaporate at a temperature of about 105 degrees Centigrade, and the contents of the kettle begin to boil, much like a liquid. When this first evaporation is completed, the boiling ceases, the contents of the kettle settle, and the temperature begins to rise much more rapidly. At about 143 degrees Centigrade a second boiling stage begins, and when this ceases the gypsum has been dehydrated sufficiently to form plaster of Paris. It is then ready to be removed from the kettle. It must be removed promptly in order to prevent further heating, which would drive off the last portions of combined water. The discharge of the finished product is accomplished by opening vents in the bottom of the kettle. Each charge of the kettle requires from two to three hours to burn properly.

To produce plaster economically, a plant must operate at least two such kettles. The cost of a single kettle, exclusive of the masonry support, is given by Eckel[1] as varying between $1,200 and $1,600. In addition to the kettles, a plaster plant must be equipped with crushing and grinding machinery sufficient to reduce the gypsum to such fineness that 60 per cent will pass a 100-mesh screen; also, equipment for handling both the raw and calcined material, and for screening and sacking the product. The average costs for producing one ton of plaster are estimated by Eckel[1] to be as follows:

Mining or quarrying cost of the gypsum	$0.30
Power used at the mill	.10
Fuel for calcining	.30
Labor	.40
Total cost of one ton plaster at the mill	$1.10

The tendency toward the development of continuous processes in order to reduce the operating costs of batch processes is felt in

the plaster industry, just as it is being felt in almost all industries today. The most satisfactory method for heating substances in a continuous process is the rotary kiln, and this form of heater is being applied to some extent to the burning of plaster. Due to the comparatively low temperatures to which plaster burning must be limited, rotary calciners for this purpose are specially designed to keep the temperature to which the material is subjected within the proper range. By the use of such calciners the burning of plaster becomes a continuous instead of a batch process, and great economies are effected in the fuel and handling costs. Average costs of burning plaster by such a process are estimated by Eckel[1] to be as follows:

	Maximum	Minimum
Mining or quarrying of gypsum	$0.72	$0.12
Power used at mill	.12	.04
Fuel for calcining	.31	.10
Labor	.30	.18
Total cost per ton plaster at mill	$1.45	$0.44

As is usually the case with the application of continuous processes, the advantages obtained by the application of the rotary calciner to plaster burning are not effective except for comparatively large unit capacities.

Gypsum occurs in several localities in Texas. The most important deposits are in an outcrop of the Permian formations, and make up a narrow strip along the eastern base of the Staked Plains in the northwestern part of the State. Gypsum is being mined from these deposits and manufactured into plaster products at the following points: Sweetwater, in Nolan County; Quanah, in Hardeman County; Hamlin, in Jones County; and Plasterco, in Fisher County.

Operations have recently been started on a deposit of gypsite of a different geologic nature near Falfurrias, in Brooks County.

There are also extensive deposits of gypsum in El Paso and Hudspeth counties, but with the exception of a small quarry near Finlay, which hauls out gypsum for the use of a cement plant, there has been no development of these deposits.

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[1]Edwin C. Eckel, "Cements, Lime, and Plasters," John Wiley and Sons, 1922.

Lime

Lime is used in mortars for masonry construction, and as such is probably the oldest cementing material. It is being replaced to some extent by the newer forms of cement, but is still extensively used. In addition to this use, it is finding ever-increasing use as a chemical reagent in the treatment of hard waters.

The cementing properties of lime depend upon the fact that calcium hydroxide, when exposed to the air, slowly absorbs carbon dioxide from the air to form calcium carbonate, as follows: $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$. A hardened lime mortar is therefore, a sort of artificial limestone. Lime mortars used to bind masonry are exposed to the air only on the surface of the wall, and the absorption of carbon dioxide penetrates very slowly to the innermost portions. Thus, it takes long periods of time—sometimes many years—for such mortars to attain their maximum strength. Lime is obtained from limestone by heating at temperatures between 750 and 900 degrees Centigrade, as follows:

$$CaCO_3 = CaO + CO_2$$

The quicklime (CaO) thus produced is then "slaked" with water:

$$CaO + H_2O = Ca(OH)_2$$

This last reaction produces a considerable amount of heat.

The slaked or hydrated lime is made into a mortar and used. In drying and hardening, slaked lime shrinks considerably and cracks badly. To overcome this tendency, it is mixed with sand in the proportions of from two to four parts of sand to one of lime, together with enough water to give the mortar the desired consistency. Too much water weakens the cementing effect. The sand used is an inert ingredient which merely overcomes its tendency to shrink and crack, and does not enter into combination with the lime.

The slaking of quicklime was originally done "on the job" as a preliminary step to the mixing of the mortar. With the crude methods of mixing available under these conditions, and the class of labor employed for this work, it was very difficult to accomplish complete slaking, and there was a great danger that either too much or not enough water would be used. There is thus a

demand growing up for lime which is already slaked, and most firms are now offering such limes for sale. The manufacturers slake the quicklime carefully with the proper amount of water and sell a product which is ready to be mixed with sand and water without any preliminary treatment.

Lime is usually burned in vertical-shaft kilns. Horizontal rotary kilns are used to some extent, but are not gaining in favor in the lime industry as rapidly as they are in other calcining operations. Their principal use in the lime industry is in burning lime which is intended to be slaked before being sold. The reason for this is that unslaked lime is preferably sold in lumps, while any material to be efficiently burned in a rotary kiln must be fed in small sizes.

Vertical kilns are made with a number of modifications. The most primitive type was of an intermittent nature and has almost disappeared from use today. In it the lumps of limestone were stacked in the shaft of the kiln and a wood fire built in the base of the stack. The hot gases passed up through the kiln between the lumps, and heated the charge. The intensity of heating was increased until the charge attained a red heat. The completion of the decarbonation was indicated by a shrinkage of the mass, and frequently required as much as four days. The fire was then allowed to die out, the charge cooled and removed. This was a simple process and gave a satisfactory product, but was very costly in fuel consumption. To burn lime on a large scale by this method would require a large number of kilns and a large plant area, as well as entailing immense heat losses.

To overcome these disadvantages vertical kilns have been devised into which the lime is fed more or less continuously at the top and the burned lime removed at the bottom without interrupting the operation. In some of these kilns the limestone and fuel are fed in alternate layers, the fire thus burning throughout the entire charge. This "mixed feed" method is very efficient in point of fuel consumption, but is limited to solid fuels and has the disadvantage of producing a lime which is contaminated by ashes and possibly discolored by contact with the fuel. In "separate feed" kilns the fires are confined to furnaces in or near the base of the kiln, and the heat is transmitted to the charge by the gases of combustion which pass up through the kiln. The disadvantages of

the mixed feed kiln are thus overcome, but the separate feed kiln is less efficient in heat utilization and is more expensive to construct.

Eckel gives the following estimates of the cost of burning lime:

	Minimum	Maximum
Interest on cost of plant and quarry	$0.05	$0.20
Taxes, minor supplies, etc.	.10	.25
Cost of quarrying limestone	.50	.90
Cost of fuel for burning	.30	.75
Labor	.25	.80
Total cost per ton quicklime	$1.20	$2.90

The differences between the maximum and minimum figures given, particularly in the fuel and labor costs, indicate the wide variations found in efficiency of operation. It is to be regretted that so little attention is paid by the lime industry to the possibilities in expert technology. Lime plants are in operation throughout the country at which not a single man is employed who is capable of dealing with fundamental engineering problems. This is true not only of small plants but of large ones with complicated installations. Investigations of a private nature have revealed appalling inefficiency in operation of large plants within this State. The fact that such plants continue to operate at a profit in spite of such conditions suggests what might be expected if intelligent and scientific control were used.

Limestones are seldom pure calcium carbonate. A notable exception in this respect is found in Texas in the Balcones lime, which is so free from impurities as to be practically chemically pure. Impurities such as those usually found (alumina, iron, and silica) dilute the lime and reduce its activity in proportion to the amount present. Such substances may combine with the lime similarly to the combinations effected in the burning of Portland cement, and give the resulting product some degree of hydraulicity, but such combinations are not very likely to occur at the temperatures of the lime kiln and with the quantities generally present in limestones used for this purpose. Limestones containing these impurities will decompose at temperatures slightly lower than will pure calcium carbonate, and the resulting quicklime will slake more slowly and with the evolution of less heat.

Magnesium frequently occurs associated with calcium in limestone, usually in the form of dolomite ($MgCO_3 \cdot CaCO_3$). This

magnesium carbonate will decompose into magnesium oxide and carbon dioxide at temperatures somewhat lower than required for the decomposition of calcium carbonate. The resulting MgO will slake with water to form $Mg(OH)_2$ and recarbonate on exposure to the air to return to the form $MgCO_3$. Both the hydration and the recarbonation, however, proceed more slowly and with the evolution of less heat than do the corresponding reactions with CaO. It has been shown that limes containing some magnesia attain greater strengths than do those containing little or none of this element. Due to the slow reactivity of MgO, magnesian limes are slower to slake, and greater care must be taken to insure their complete hydration. They are also much slower to attain their ultimate strength.

An application of lime which is of particular interest to the clay industries is found in "lime-sand" bricks. A mortar of lime and sand is well mixed and molded into bricks. These are dried and laid up in walls in the same manner as clay bricks. Sometimes the drying and hardening is hastened by heating with steam or other means. It has been claimed that this promotes a combination between the lime and the sand which increases the strength, but this has not been proven. Fresh lime-sand bricks have no great strength or harness, but attain it with age.

Lime is of extensive occurrence in Texas, and is quarried and burned in kilns at various points. The largest plants are at New Braunfels, McNeil, Round Rock, and El Paso. One plant at Houston manufactures lime from oyster shells. There is a company making lime-sand bricks at San Antonio.

Hydraulic Cements

Cementing materials which have the property of hardening under water have been known for a good many years. The ancient Romans used a cement made by mixing volcanic ash with ordinary lime which possessed this property to a limited extent. Several other classes of materials, such as hydraulic limes, natural cements, and puzzolan cements, were discovered more or less accidentally, and are all based on the tendency of clayey substances, when heated with lime, to form compounds which will *set* in contact with water. All of these can be considered as steps in the development of the

Portland cement of today. Portland cement has replaced most of these materials, but they are still in use to a limited extent in some places, notably in France. The most common forms are "natural" cements and "Grappier" cements. The latter are made by grinding the hard lumps which result from the presence of clay in limestone when the limestone is burned in kilns; these lumps can be readily separated from the softer lumps of quicklime. Natural cements are made by burning calcareous clays or argillaceous (clayey) limestones. When such substances are mixed in the correct proportions with other substances so as to bring the resulting mix to exactly the correct composition, and burned to the proper temperature, the product obtained is in all respects equivalent to Portland cement.

In 1824 Joseph Aspin took out an English patent on an improved type of cement which he proposed to make by first mixing limestone and clay, calcining this mixture, and then grinding the resulting product to a fine powder. He called his product "Portland" cement, because when hardened it resembled the yellowish-gray stone which was quarried at Portland, England.

While Aspin is usually credited with the invention of Portland cement, it is quite likely that the extent of his contribution to the invention was the name of the product. There is no indication that he carried the process of calcination to the point of incipient vitrification which is now recognized as necessary in the manufacture of Portland cement. His product was merely one step in advance of the natural cements which preceded him, in that he mixed the two ingredients, making some attempt to keep a proper proportion.

Following this invention, the development of Portland cement has been rapid. The value of burning to such a temperature as to vitrify the mixture into a hard "clinker" and the advantages of grinding this clinker to a fine flour were discovered. The Germans recognized the value of this new product, and by systematic researches and the application of expert technology in the place of the rule-of-thumb methods which had been used, soon led the world in the manufacture of a more uniform and high-grade product. Other countries have caught up in this matter, and today the best Portland cement made in the world is probably that which is made in America.

Portland cement was originally designed to replace lime mortar in places where the structure was in contact with water so that the lime would not set. However, its many advantages over lime has caused it gradually to replace that material and to grow in importance until it is now ranked among the most important structural materials. The great development in this industry has taken place in the last forty years. The Dodge statistics show that while the contracts for building construction for the year 1925 were 33 per cent higher in total square feet than for the year 1922, in the same period the manufacture of Portland cement increased 42.5 per cent. This indicates how rapidly Portland cement is gaining in favor as a structural material.

Portland cement is one of the best materials for the construction of highways, and is replacing asphalt and other road-building materials. It is used in the construction of dams, retaining walls, sidewalks, curbs, etc. It is being made into blocks and bricks for building construction, and into sewer pipe and drain tile. The advantage gained in the manufacture of such ware from cement is that the simplicity of the process makes it possible to locate plants for the forming of the ware in close proximity to almost every market. As a consequence, these products can be delivered where needed at a much lower figure than the competitive product in the clay line. The rapid development of the industry is indicative of the growing favor with which these products are being received. The development of reinforced concrete has brought cement into use in the place of structural steel in large structures. This development has been possible due to the fact that concrete and steel have nearly the same coefficient of expansion, so that steel bars can be placed in concrete members and furnish the tensile strength necessary, while the concrete will withstand the shearing and compressive stresses to which the member is subjected.

Portland cement is an artificial product of closely limited chemical composition. The constituents are lime (60 to 65 per cent), silica (20 to 25 per cent), and iron and alumina (5 to 12 per cent). While the constituents may vary within the limits shown, the variation of each is interrelated with and dependent upon that of the others, and is influenced to some extent by the amount and nature of any impurities which are present. A slight variation in

the percentages of the minerals present in the products from different localities is to be expected, but for a single plant this variation must be controlled within very narrow limits in order to put out a product of uniform quality. Accurate chemical control of the mix which is fed to the kiln must be maintained at all times in order that the various constituents will be present in the correct proportions to produce the reactions desired.

It is therefore apparent that the manufacture of Portland cement is basically a chemical industry. Limestone and clay, or materials which contain the same mineral constituents, are mixed in the proper proportions to produce certain chemical reactions. In order that this may be accomplished, raw materials of the correct chemical and physical character must be intimately mixed in the correct proportions. This mixture is then heated to a temperature of between 1,400 and 1,500 degrees Centigrade, so that the ingredients will react chemically to produce the desired ingredients in the clinkered mass. The clinker thus produced is then ground to a fine powder, and this powder, with the possible addition of certain minerals during the grinding process, constitutes Portland cement.

The essential constituents mentioned above—lime, silica, and alumina and iron—are widely distributed in nature and occur in many forms in many different rocks. It is therefore conceivable that a satisfactory Portland cement mixture could be prepared from any one of an infinite number of raw materials. But the expedience of commercial practice has eliminated a large number of materials which could be used if the chemical composition were the only criterion which had to be considered. Some materials are too scarce, or are too valuable for other purposes, to be used in the manufacture of cement. Others are too difficult to grind economically or require too high a temperature to become chemically active. Consequently, the number of materials which are actually being used in the manufacture of this product are comparatively few, and in general may be said to be limited to the common grades of clay and of limestone. In a few plants slags resulting from metallurgical process have been used in place of clay to supply silica, alumina, and iron. Argillaceous limestones are found in some localities which contain both the essential substances already mixed, and by proper plant design and manipulation of the process

can be manufactured into Portland cements. Such natural mixtures are desirable, since their constituents are usually so intimately mixed as to reduce the amount of mixing necessary in the process, but it is seldom that they contain the constituents in the proper proportions. Sometimes a quarry will contain several strata, each of a different composition. By properly proportioning the amounts of material taken from the several strata, the mixture going to the kilns may be made to have the correct proportions. If such a mixing is not possible, provision must be made for obtaining from some other source the necessary lime or clay to give the mix the proper composition.

A number of different methods, mostly empirical, are in use for the calculation of the proportions of clay and limestone for a cement mix. Any book on cement technology will give these methods in detail. The reader is referred particularly to the following:

"Cement, Concrete, and Bricks," by Alfred E. Searle, Van Nostrand, 1926.
"Cements, Limes, and Plasters," by Edwin C. Eckel. John Wiley and Sons, 1922.
"Portland Cement," by Richard K. Meade, The Chemical Publishing Company, 1926.

Much research work has been done on the constitution of the cement clinker. It has been found that there are three essential mineral constituents. Tricalcium and dicalcium silicates are present in about equal proportions, but the percentage may vary within wide limits without affecting the properties of the product to any great extent. The third common constituent is tricalcium aluminate. This mineral has very feeble cementing qualities. Its presence improves the plasticity of the cement, but its chief value in the mixture is that it acts as a flux for the other constituents and permits the formation of a clinker at commercially attainable temperatures. Commercial cements also contain small amounts of other minerals which are due either to impurities in the raw materials or to substances which were added during grinding to develop certain properties in the cement. In the latter class are those substances which are added to either accelerate or retard the setting of the cement. The following references are to recent literature covering researches on the composition of cement clinker and on the effect of accelerators and retarders:

Rankin, Jour. Ind. and Eng. Chem., VII, p. 416.
Ernst Jaenecke, Zement, 17, pp. 756–60 and 792–7 (1928).
A. Dahlgren, Zement, 18, p. 111 (1929).
F. Killig, Zement, 18, p. 256 (1929).
Ernest E. Berger, Rock Products, 31, No. 25, p. 50 (1928).
W. J. Pitt, Chem. Eng. Mining Rev., 20, p. 402 (1929).
C. R. Platzman, Tonind. Zeitung, 53, p. 59 (1929). This contains a review of the literature on the use of gypsum and anhydrite in control of the setting time of cement.

The setting of cement is a process of hydration of the minerals present. Normal Portland cements begin this reaction with an "initial set" very soon after they are mixed with water, and then take a "final set" after ten hours or more. Even after the final set the process of hardening goes on for some time, the ultimate strength frequently not being attained for a year or more. Cements that take the final set in less than ten hours are called "quick setting." For some purposes quick setting is desirable, and for these purposes the composition of the cement is so controlled as to bring about such a result. Cements are being made which take their final set within thirty minutes of the time they are "gauged" with water. For most purposes, however, it is more desirable to retard the setting, as this results in greater ultimate strength. A great deal of research work has been done on the theory and mechanism of the setting and hardening of cements. For the recently published reports along this line the reader is referred to the following:

R. H. Bogue, Rock Products, 31, No. 10, p. 69 (1928), a digest of the literature on the subject.
R. Nacken, Zement, 16, pp. 1017–23 and 1048–51 (1927); Pit and Quarry, 15, p. 79 (1928).
Tutomu Maeda, Sci. papers Inst. Phys. Chem. Res. (Tokyo), 8, Suppl. 2, p. 5 (1928).
K. Biehl, Zement, 17, pp. 487–92, 824–8, and 934–7 (1928).
Hans Pulfrich and G. Linck, Koll. Zeitung, 34, p. 117 (1924).
A. A. Jakkula, Eng. News Rec., 99, 955 (1927).
W. N. Thomas and N. Davy, Bldg. Res., Spec. Rep. 13 (1929).
Hermann Gessner, Koll. Zeitung, 46, p. 207 (1928), and 47, pp. 65 and 160 (1929).

When a cement sets, only a comparatively small proportion of the available cementing constituents actually hydrate. A set and hardened cement may be reground, gauged with water, and will set again, some of the constituents which were left unchanged the first time hydrating the second time to produce another set. The proportion of the constituents which is thus effective may be increased by finer grinding of the clinker, and the tendency in the cement

industry has been toward finer and finer grinding. The most common means of effecting an increase in the efficiency of cement, however, is by making concrete by mixing the pure cement with an "aggregate" of inert matter such as sand or gravel. In concrete the cement particles are dispersed throughout a greater space by the presence of the aggregate, and a greater proportion of them is effective in setting. This affects a great economy in the amount of cement used. The nature of the aggregate, its coarseness and quantity is determined by the nature of the work. Factors influencing the composition of concrete are discussed in books dealing with cement and concrete, and will not be discussed here.

Raw materials suitable for the manufacture of cement are found in great abundance in Texas. For the successful operation of a cement plant, however, more things must be considered than the availability of the raw materials. Of course, the two essential constituents, clay and limestone, must be found in close proximity to each other, but such occurrences are more or less common. Due to the abundance of the raw materials, it may be said in general that the availability of them is one of the less important considerations entering into the planning of a new cement manufacturing enterprise. The more important considerations are of an economic nature—the fuel and labor supply, and the market conditions. If an organization is formed, financially capable of building a plant of the necessary size, and operating it until it gets into production, and working up a market large enough to absorb the output of the plant, they will have little trouble in finding suitable raw materials.

Cement plants cannot operate economically on small capacities. Meade[1] states that the minimum capacity for which a plant may be designed to give good results is 1,200 barrels per day. He also estimates the total cost of a cement plant to vary from $3 to $5 per barrel of annual output. The minimum cost of a plant of the smallest capacity economically possible would thus be in excess of $1,000,000. Before an enterprise can be started, there must be available enough money not only to build the plant but to operate it until the sales of the product will begin to pay the operating expenses. The plant must be planned so that the cost of manufacturing the cement will be low enough so that the difference between

[1]Richard K. Meade, "Portland Cement," Chemical Publishing Co. (1926).

this cost and the price for which the cement can be sold is great enough to pay a profit on the investment. The cost of manufacturing cement is divided as follows:

A. Quarry costs; quarry labor and supplies and cost of transporting the raw materials to the mill.
B. Mill costs; labor, power, fuel, supplies, superintendence, laboratory supervision, and repairs.
C. Administration costs; general offices, sales and advertising expenses.
D. Fixed charges; Insurance, taxes, depreciation and obsolescence of equipment and buildings, and exhaustion of raw material supply.

The process of manufacture of Portland cement will be briefly described. The first step is the preliminary crushing of the raw materials. The trouble and expense of this step varies, of course, with the hardness of these materials. After they are crushed, the two constituents, mixed in the proper proportions, are fed to the grinders, where they are reduced to the necessary fineness and also intimately mixed at the same time. If the cement is to be manufactured by the "dry process," this grinding is carried to the point where the dry powdered mixture will pass 95 to 98 per cent through a 100-mesh screen. With softer materials the "wet process" is sometimes used, in which the crushed mixture is mixed with water and stirred up until it forms a thin paste or "slurry," in which form it goes to the kiln for burning. A great deal more heat is used for burning this slurry than is necessary for the dry mixture, but this extra cost is made up for by the lesser cost of grinding, and the advantage in securing a more uniform mixture. The mixture then, dry or wet, is fed to the kilns, in which it is heated to a temperature between 1,400 and 1,500 degrees Centigrade, and is thereby partially fused until it comes out in hard lumps or clinkers. The clinker is then cooled and ground to a very fine flour. This flour is at least so fine that 95 per cent will pass a 100-mesh screen, and frequently is carried much finer than that. The product must then be filled into sacks or barrels before it is ready for the market.

In grinding cement raw materials several types of machinery are used. Limestone usually requires more preliminary crushing than does the clayey constituent, though if a hard shale is used it may require a considerable amount of power for crushing. For this preliminary crushing, jaw-crushers or Gates crushers are usually

used. The materials coming from them are then mixed in the correct proportions and are ground to the necessary fineness. They usually require drying before they can be ground, because the amount of moisture which they naturally contain will reduce the efficiency of the grinding machinery by clogging. Some form of rotary drier is used for this purpose, from which the dried mixture passes to the grinders. These are of various types. The fine grinding is usually done in a ball or tube mill, but if there is a good deal of grinding necessary, the first pulverizing is done in some such device as the kominutor, Williams mill, Raymond pulverizer, rolls or disintegrator. From these the powdered mixture passes to the ball or tube mill, and from here the finely ground and intimately mixed material passes to the kilns.

When the wet method is employed, the preliminary drying is not required because the materials are mixed with water after being crushed. The amount of water is determined by the consistency desired for the slurry. The mixture of raw materials and water is intimately mixed and reduced to a pasty consistency in some such device as a paddle mill, pug mill, or wet ball or tube mill. From this mixing and grinding machinery the slurry passes to storage tanks, from which it is fed to the kilns.

Cement mixtures have been burned in upright shaft kilns, intermittent chamber kilns, and Hoffman ring kilns, but these have been almost entirely replaced by the continuous rotary kiln. For cement burning these have been made in steadily increasing sizes. Some idea of the sizes, capacities, and fuel consumptions of rotary kilns for cement plants may be gained from the following table, which was compiled from data given by Meade:[2]

Dimensions of Kiln Diam. × Length	Dry Process		Wet Process	
	Capacity bbls. Per Day	Fuel Used lbs. Coal Per bbl. Cement	Capacity	Fuel Used
6′ × 60′	200	110	140	140
6′ × 100′	300	88	210	118
7′ × 100′	430	94	300	124
8′ × 125′	700	97	490	127
9′ × 150′	1,100	100	770	130
9′ × 200′	1,400	88	980	118
10′ × 200′	1,775	88	1,245	129
10′ × 250			1,540	118

[2]Richard K. Meade, "Portland Cement," Chemical Publishing Co. (1926).

When coal is used it must be powdered before being fired in the kiln, and the powdering and handling equipment is an important accessory to a coal-fired kiln. Many kilns, particularly in this part of the country, are now being fired with oil or gas. In calculating fuel requirements from the above table it may be considered that one gallon of oil is equivalent to ten pounds of coal and that ten cubic feet of gass is equivalent to one pound of coal.

It has been found that longer exposure to heat accomplishes just as much in the way of clinkering cement mixes as do much higher temperatures such as might fuse them and injure them. Thus, a longer kiln effects a fuel saving by keeping the material in the hot space for a longer time. The same effect could, of course, be accomplished by turning the kiln more slowly, but this would reduce the kiln capacity.

The clinker coming from the kiln must be cooled and ground. In modern plants some attempt is always made to utilize the heat of the clinker. This is usually done by cooling it in a rotating drum through which cold air is drawn, the air cooling the clinker, and then, being heated itself, is used either for combustion in the kilns or for drying the raw materials.

The cooled clinker is first crushed and then ground to a fine powder in a ball or tube mill. Either a screen on an air separator system must be provided to remove the coarse particles and return them to the mill. The fine product is then placed either in sacks or barrels, and is ready for shipment. A cement barrel holds about 376 pounds of cement, and in general it requires about 600 pounds of raw materials to produce one barrel of finished product.

Several other operations are usually necessary in the production of cement, such as storage of the ground clinker for some time before packing, and addition of gypsum or other retarder to the clinker during grinding, but these will not be discussed here.

The following recent journal articles contain descriptions of modern cement plants:

C. H. Sonntag, Chem. and Met., 35, p. 623.
Anon., Pit and Quarry, 17, No. 7, p. 33.
C. G. Thornburgh, Cement Mill and Quarry, 34, No. 5, p. 13.
Hal Gutteridge, Proc. Inst. Mech. Eng., 1927, p. 781.
Anon., Engineering (England), 121. p. 681.

Anon., Engineering (England), 137, p. 326.
F. Ferrari, Cemento (Italy), 20, 101 (1923).
Wm. L. Norton, Black Hills Engineer, 12, p. 65.
C. H. Breakin, Rock Products, 27, No. 18, p. 53.
G. M. Earnshaw, Rock Products, 27, No. 9, p. 45.

There are at present cement plants operating in the State of Texas as follows: Two at Dallas, one at Fort Worth, two at San Antonio, one at Waco, one at Houston, and one at El Paso. Statistics as to the total capacities of these plants are given in Chapter I.

CHAPTER V

SPECIAL CERAMIC MATERIALS

KAOLIN

Kaolin is the name given to high-grade clays, also frequently called china clays because of their use in the manufacture of china-ware. As previously mentioned (Chapter II), the mineral kaolinite was so named because of the assumption that it was the essential mineral constituent of kaolin. The mineral form itself is seldom present in any very great amount in kaolin, but high-grade materials frequently are found to approximate very closely the chemical composition represented by the formula $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$. Expressed in percentages, this composition is as follows:

	Per Cent
Al_2O_3	39.8
SiO_2	46.3
H_2O	13.9

Kaolin is highly refractory; the pure substance does not begin to fuse until heated to a temperature of 1,785 degrees Centigrade, corresponding to cone 35. It usually possesses a fair degree of plasticity, and high drying and firing shrinkages. In pottery and white ware mixes, kaolin is mixed with quartz and feldspar. The function of the quartz is to reduce the shrinkage of the kaolin. Feldspar also aids in this respect, and also acts as a flux for the highly refractory kaolin and quartz. Without the addition of the comparatively easily fusible feldspar it would be impossible to mature such ware at temperatures which are commercially obtainable. The proportions used in such a mix are usually something like the following, although they vary in accordance with the character of the ware to be made and with the purity and physical condition of the constituents: Fifty parts of kaolin to twenty parts of feldspar and thirty parts of quartz.

The chemical analysis of a kaolin sample tells the amounts of such impurities as iron, lime, magnesia, and alkalies as may be present. All of these are undesirable in a clay of this type. Some of them are usually present, but if more than very small amounts

are present the value of the kaolin is materially reduced. In addition to the chemical analysis, a kaolin sample must be tested to determine its dry and fire shrinkage, and the tensile strength of the air-dried material. All of these properties must be known to determine the value and use of a kaolin. In addition to these tests, to determine adaptability to specific types of ware it must be mixed with the proper amounts of quartz, feldspar, etc., made up into test pieces, and fired, to observe the behavior under these circumstances. These fired pieces should be observed with regard to the following properties: Translucency, vitrification range, color, shrinkage, and any other properties which may be of importance in the type of ware which is involved.

Naturally occurring kaolins are usually washed free from impurities before being used. This refining process necessitates washing, settling, filtering, and drying equipment, and thus adds materially to the cost of the kaolin: but, for the uses to which kaolin is put, this extra cost is repaid in added value of the product.

Kaolin is supposed to occur at a number of points in the State of Texas, but the most important deposit, and the only one which has been examined with sufficient thoroughness to prove its value, is located in Real County, five miles northwest of the town of Leakey. Some years ago Dr. E. P. Schoch, of this Bureau, made an extensive study of this deposit at the request of parties interested in its development. He made a report on his investigation in August, 1921. This report covered the nature of the deposit, recommendations for methods of working, and estimates of the costs and prices involved. Because of the general interest which this deposit has, and because of the large amount of information which this report contains, it is printed here in full. Mr. R. W. Wortham, representative of the G. M. Dodge estate which estate owns the land on which this deposit occurs, has kindly given permission for this information to be made public.

Report of Dr. E. P. Schoch on the Kaolin Deposit on Section 71, Block 3, T. W. N. G. R. R. Co. Survey, Five Miles Northwest of Leakey, Real County, Texas.

Location and Accessibility

The kaolin deposit herein described is located on Sec. 71, Blk. 3, T. W. N. G. R. R. Co. Survey, five miles northwest of Leakey,

the county seat of Real County, Texas. The deposit is found in a shallow draw, between slight elevations, on a small plateau about 600 feet above the valley of the Frio River, at an elevation of about 2,500 feet above sea level. Geologically, the surface rock is known as the Edwards Limestone. The wagon road from Leakey to this deposit was used at one time to haul the material to the Southern Pacific Railroad at Uvalde or Sabinal, a distance of forty-five miles. At one point this road ascends 500 feet in the distance of one mile, and is very rough. The rough character of this road, together with the distance to the railroad, made shipipng rather costly.

Since the Uvalde and Great Northern Railroad has been completed up the Nueces Canyon to Camp Wood, and since the latter is only fifteen miles southwest of the deposit, it became desirable to locate a road by means of which the kaolin could be hauled cheaply to Camp Wood. Mr. Proc Webb, the foreman of the exploring party employed in connection with this report, located such a road, and took Judge W. D. Love over it. The writer inspected a portion of the proposed route. Starting in the draw in which the kaolin deposits are located, it continues down the draw northward for a short distance, then curves to the south on Sections 67 and 68, thence through the draw in which the Mills ranch house is located. Beyond this the writer is unable to state the exact course of the road. It leads over practically open, flat ground which will require very little work to clear of timber and other obstruction. Mr. Webb stated that the road would have a downward grade all of the way to Camp Wood, with the exception of one place where there would be a moderate up grade for a distance of less than a mile. The length of the road to Camp Wood is about seventeen to eighteen miles, and it will cost about $2,500 to make it usable for trucks.

Description of Kaolin Deposit

In order to locate the deposit definitely on Section 71, reference will be made to the accompanying blue print (reproduced in this bulletin as Figure 17). Point No. 1 on this map is 1,060 yards from the north edge of Section 71 and 425 yards from the west edge. At this point the company which at one time removed kaolin from this deposit had dug a well about forty feet deep, and this well was cleaned out and dug deeper. It proved to be situated well within the kaolin deposit, and hence the depth and width of the deposit was accurately ascertained at this point, as will be presented further on. Point No. 1 is on the east side of the draw, which drains northward along the "line of water flow," shown on the map. Points 1 to 14 all represent test wells which have been dug to ascertain the character of the deposit at these various points.

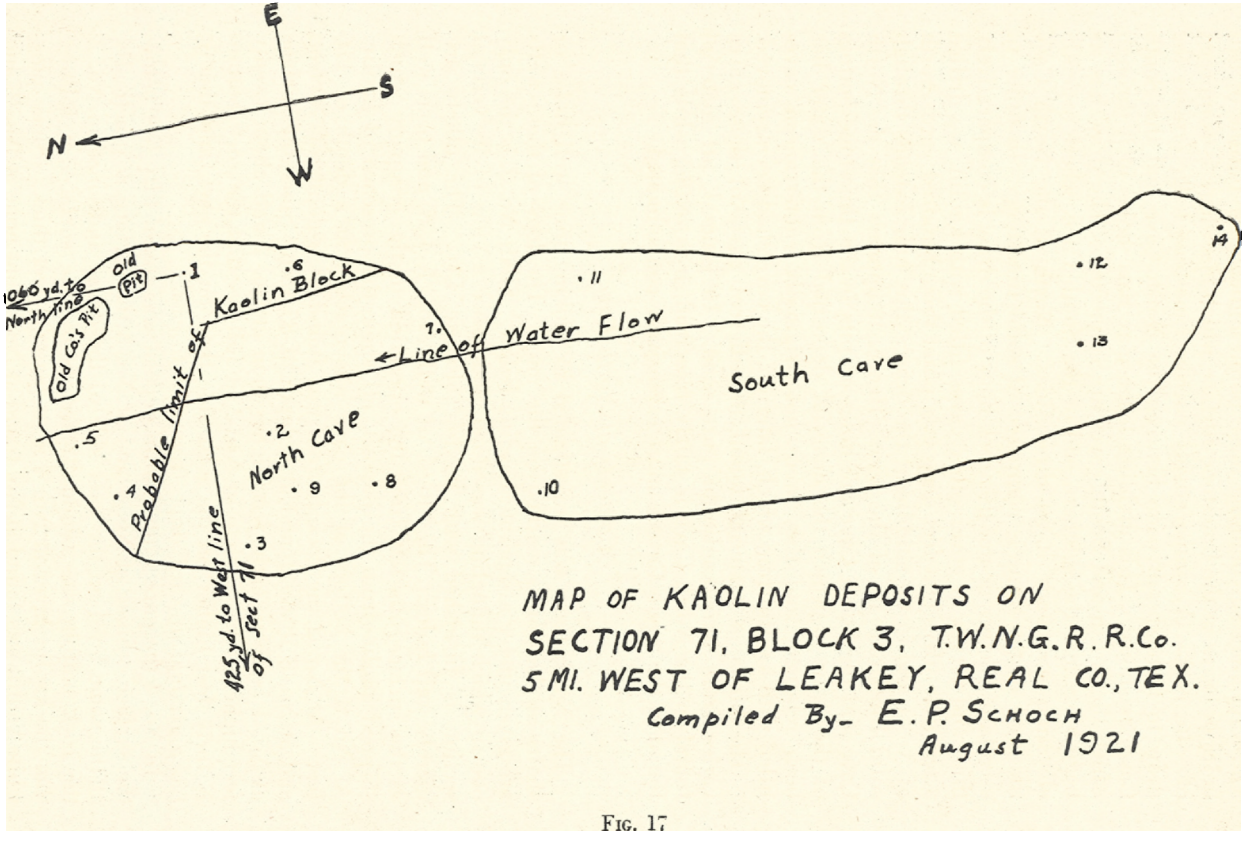
E
S
N
W
1060 yd. to North line
Old Pit
Old Co.'s Pit
Kaolin Block
Probable limit of
Line of Water Flow
South Cave
North Cave
425 yd. to West line of Sect 71
MAP OF KAOLIN DEPOSITS ON
SECTION 71, BLOCK 3, T.W.N.G.R.R.Co.
5 MI. WEST OF LEAKEY, REAL CO., TEX.
Compiled By- E. P. SCHOCH
August 1921

FIG. 17

The wavy lines surrounding these points indicate the outline of two holes or caves in the limestone surface which elsewhere is composed of solid rock. A comparatively narrow limestone ledge crosses the draw to form the division between the North Cave and the South Cave, as shown. This dividing ledge may have holes in it through which the North and South caves are connected. The draw has its beginning near the southern end of the South Cave, where a gentle elevation surrounds it on three sides. North of the North Cave the floor of the draw is composed of solid limestone. In order to ascertain whether or not this rock floor of the draw is comparatively thin, and serves to cover other caves filled with kaolin, we drilled a test hole fifty-eight feet deep at a point three hundred yards north of No. 1 and in the middle of the draw; this hole extends through solid limestone all of the way. Hence, it appears that the North Cave and the South Cave are holes or pits in the limestone bottom of the draw in which the material deposited from the water has been retained, and they were not originally subterranean caves filled with kaolin from which, later on, the cover had been removed.

The kinds of material found in different parts of these caves varies from pure kaolin to pure sand. In general, all material found in the North Cave is fairly free from iron oxide, while that found in the South Cave is more extensively contaminated.

Contents of North Cave

The North Cave was investigated by sinking nine well holes or shafts at the points marked on the map. The logs of these wells are given under a separate heading below. Shaft No. 1 is the only one in which tunneling was done, and hence a view of its vertical section is furnished with its log (Figure 13). The others are merely well holes. The "logs" of wells Nos. 1, 4, 5, and 6, as well as the surface pits left from the operation of the company which shipped kaolin from the deposit, all show the presence of kaolin. At No. 1 the bottom of the cave was reached at a depth of 116 feet. At No. 2 the rock bottom was found at a depth of 74 feet, and at No. 3 it was found at a depth of 87 feet. Since the surface at No. 1 is about eight feet higher than at No. 2 and about twenty feet higher at No. 3 than at No. 2, it follows that the rock bottom is forty feet higher on the west side than on the east, and that it has a gradual upward slope from west to east.

In No. 4 the pure white kaolin deposit was found fifty feet below the surface. Since at No. 4 and at No. 3 the surface is practically at the same level on the west side of the draw, and since in No. 3 the rock bottom was found 87 feet below the surface, it follows that the kaolin layer at No. 4 is *at least* 37 feet thick. Since pure white kaolin was found at No. 6 and at No. 4, but none at No. 2, and since, furthermore, this block of kaolin extends only about 75 feet

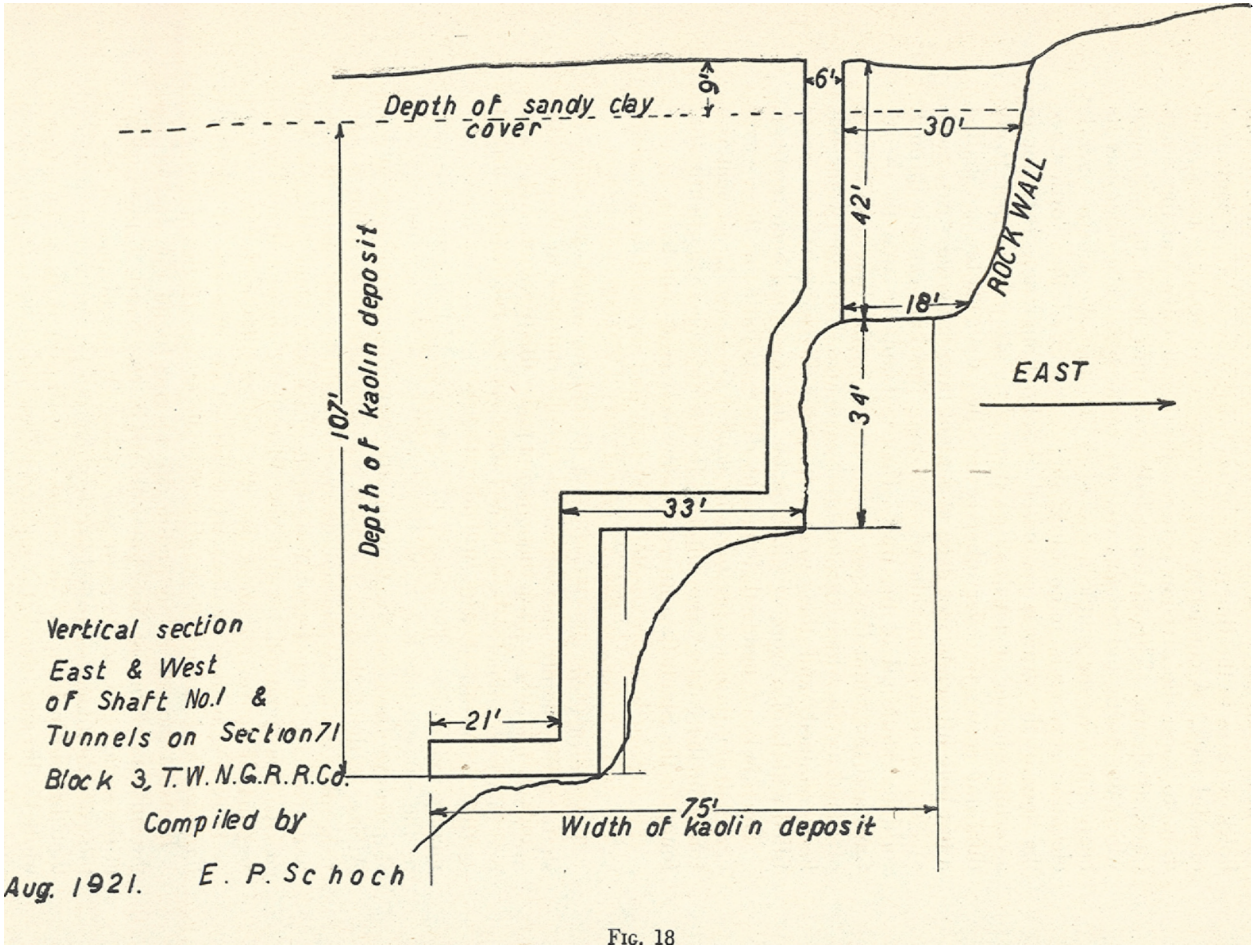
Depth of sandy clay cover
9'
6'
30'
42'
ROCK WALL
18'
EAST
34'
107'
Depth of kaolin deposit
33'
21'
75'
Width of kaolin deposit
Vertical section
East & West
of Shaft No.1 &
Tunnels on Section 71
Block 3, T.W.N.G.R.R.Co.
Compiled by
Aug. 1921. E. P. Schoch

FIG. 18

from the east wall at No. 1, it is probable that the limit of this kaolin block is the line crossing the North Cave about 65 feet south of No. 4 and running to a point 75 feet west of No. 1, thence southeast so as to pass 25 feet west of No. 6, and that the kaolin block fills all of this northeast corner of the North Cave up to this line.

From the map it appears that the larger part of the kaolin block has approximately the shape and dimensions of the prismoid shown in the accompanying sketch (Figure 19). This prismoid has a content of 2,534,000 cubic feet. Since this kaolin has an apparent specific gravity of 2.36 (as determined in this laboratory), a cubic foot of this kaolin, dry, weighs 144 pounds. Hence, the weight of the above amount of kaolin would be 182,400 tons. I believe it is safe to assume that there are at least 140,000 tons of pure kaolin in this deposit, and that the amount deducted is sufficient to allow for all the kaolin taken out by the old company, and for such other possible differences between the real outline of the kaolin block and the prismoid above as may happen to exist.

In wells Nos. 2, 3, 8, and 9 there was found a white sandy clay, which is discussed farther on under the head of "Fire Clay." This probably fills the southwest corner of this cave to an average thickness of fifty feet, after deducting the thickness of the layers of sand with which it is interspersed. The north and south length of this deposit is approximately 300 feet, and its width approximately 250 feet; hence, it has a content of 3,750,000 cubic feet. Its apparent specific gravity is 2.47, so that its weight per cubic foot is 154 pounds, and this deposit of fire clay amounts to about 288,700 tons. It is likely that there is not only this amount, but perhaps more of it in the North Cave, and there are several hundred thousand tons of similar material in the South Cave.

Contents of South Cave

In the South Cave wells were dug, as shown on the map, at points Nos. 10 to 14, the logs of which are given elsewhere under a special heading. Most of this cave seems to be filled with sand. However, in No. 10, at a depth of 62 feet, a ten-foot layer of pure white kaolin was found. Wells Nos. 11 and 12 showed that there is a block of sandy clay along the east wall of this South Cave. At No. 11 this clay contains too much iron (see analysis of sample K, under the heading of "Analyses"), but at No. 12 the material (see analysis, sample H) is practically identical with the washed material obtained from the fire clay from the North Cave, and this material will serve to increase appreciably the tonnage of fire clay available whenever it is used.

The west bank of the South Cave has not been investigated, partly because the wells sunk in the South Cave revealed only the small amount of white kaolin found in No. 10 (and this was found

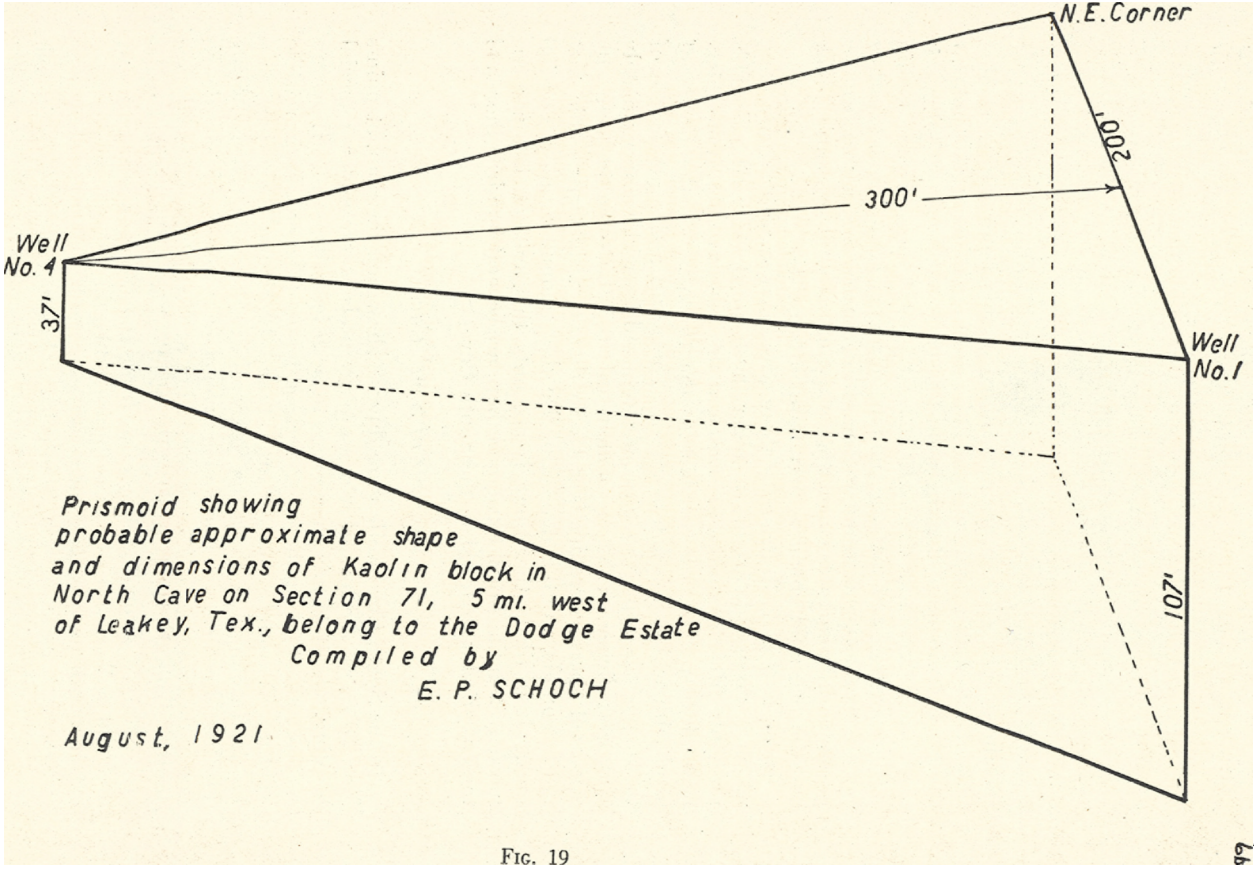
N.E. Corner
200'
300'
Well No. 4
37'
Well No. 1
107'
Prismoid showing
probable approximate shape
and dimensions of Kaolin block in
North Cave on Section 71, 5 mi. west
of Leakey, Tex., belong to the Dodge Estate
Compiled by
E. P. SCHOCH
August, 1921

FIG. 19

at considerable depth), and partly because there were no surface indications of any promise, and our "wildcat" digging had been carried as far as it seemed to be justifiable. However, the occurrence of pure kaolin in No. 10 renders it possible that some material of value may be found in the South Cave.

Logs of Wells

No. 1 (See drawing of vertical section, Fig. 18)

0– 9 ft.—Sandy cover.

9– 42 ft.—Kaolin with "blue" portions. At 42 ft. a rocky ledge was struck. A tunnel was extended east for 18 feet, until the east wall of the cave was struck; this tunnel extended entirely through kaolin, much of which was soft and water soaked.

It was found that the cave wall extended vertically downward a few feet west in the shaft, hence the shaft was deflected slightly to the west and continued downward.

42– 76 ft.—Hard, flinty kaolin. Here the rock wall of the cave prevented further progress downward, and a tunnel was run west for a distance of 33 ft. It extended through pure white kaolin without reaching the end of the latter. At the end of the shaft the kaolin was soft, waxy, and moist. Then a shaft was sunk from the west end of this tunnel.

76–116 ft.—Pure kaolin, fairly hard. At 116 ft. the rock wall again prevented further digging, and a second tunnel was run west 21 ft. It was terminated there because the softness of the kaolin made further digging dangerous unless the tunnel was carefully timbered. The large amount of water, and presence of sand at the end of this tunnel indicate that the kaolin block does not extend appreciably further. It was also noted that the rock at the bottom of the tunnel extends practically to the end—in other words, that the bottom of the cave had been reached.

No. 2.

0– 5 ft.—Reddish clay.

5– 64 ft.—White sandy clay—see analysis of sample F.

64– 74 ft.—Sand.

74 ft.—Rock.

No. 3.

0– 4 ft.—Red clay.

4– 35 ft.—White sandy clay.

35– 55 ft.—Sand.

55– 87 ft.—White sandy clay, richer in clay than the upper stratum.

87 ft.—Rock.

No. 4.

0– 50 ft.—Red sandy clay.

50– 70 ft.—Pure white kaolin. Work discontinued because it appeared unnecessary to go deeper.

No. 5.

E. Hobbs, a workman employed in this exploratory work, stated that the old company removed 30 feet of overburden at this point and went through 30 feet of pure white kaolin. Then the workmen quit the hole on account of the danger of its collapsing. An examination of the place revealed kaolin strewn around which corroborated Hobbs' account.

No. 6.
0– 7 ft.—Sandy clay.
7– 25 ft.—Pure white kaolin. Work discontinued because it appeared unnecessary to go deeper.

No. 7.
0– 50 ft.—Sand and sandy clay.

No. 8.
0– 5 ft.—Reddish clay.
5– 22 ft.—White sandy clay—see analysis of Sample F. Work discontinued because it appeared unnecessary to go deeper.

No. 9.
0– 5 ft.—Reddish clay.
5– 34 ft.—White sandy clay—see analysis of Sample F. Work discontinued because it appeared unnecessary to go deeper.

No. 10.
0– 10 ft.—Ferruginous sand.
10– 48 ft.—Pure white sand.
48– 58 ft.—Chocolate colored sandy clay.
58– 62 ft.—Limestone.
62– 72 ft.—Pure white kaolin.
72 ft.—Rock. Well collapsed from blasting done to go through rock.

No. 11.
0– 20 ft.—Chocolate colored clay.
20– 28 ft.—Yellow clay.
28– 40 ft.—Blue clay which streaks red. See analysis Sample K.
40– 43 ft.—Very hard bluish crystalline limestone.
43– 80 ft.—White sand, like that in 10. Shaft collapsed and was abandoned.

No. 12.
0– 10 ft.—Sandy soil.
10– 80 ft.—Light blue clay. See analysis Sample H.

No. 13.
0– 90 ft.—Sand with little clay.

No. 14.
0– 20 ft.—Sand and limestone.

Physical Properties of Kaolin Samples

The kaolin obtained from this deposit varies from a dense flinty mass (sample C) to a soft, tallow-like mass with a pseudo-crystalline appearance (sample A). In the middle of the kaolin block in the North Cave the material is dense and flinty and remarkably free from any coloring matter. Toward the top it is interspersed with a bluish mass (see sample B); this mass is a mixture of sand and kaolin, and owes its color to iron (see analysis of samples A, B, and C). This bluish contamination is easily separated from the pure kaolin by "blunging" the material with water and allowing the mixture to stand a short time. The blue, sandy portion settles to the bottom and the pure white kaolin may be readily removed by decanting the liquid.

In many spots the hard, flinty kaolin is stained with red iron oxide (see analyses Da, Db, and Dc). This stain is apparently more

difficult to wash out than the blue stain mentioned above. As a matter of fact, the main difference is the treatment necessary to change the hard, shaly kaolin to a plastic mass. While it is evident from the occurrence of the kaolin that water changes the hard, flinty material to a plastic mass, yet it is a fact that a long time is necessary to accomplish this change unless the material is ground with water in a ball mill or in a blunger in which pebbles are rolled around on the bottom. The kaolin must be thoroughly disintegrated before it will remain suspended and allow the iron oxide to settle out free from extensive amounts of kaolin. Sample E represents such material purified in this way from flinty kaolin which was originally contaminated with iron oxide. Its analysis shows that the percentage of iron can thus be reduced to 0.2 per cent and less. The light pink shade of this sample is frequently seen in washed kaolin, and is merely superficial.

Some of the pure white kaolin was ground fine in an "edge-runner" mill and made up into two series of bricklets, one in which the material was made up with water into a stiff mud, and the other in which it was pressed into bricklets with the least quantity of moisture with which it would cohere—"dry-pressed." In connection with the making up of the stiff mud bricklets it was found that the water required to produce a plastic consistency was 40 per cent of the weight of the dry kaolin. The apparent specific gravity of the kaolin is 2.36. On drying, the bricklets shrank an average of 11.77 per cent of their volume.

On firing these two sets of bricklets, the following results were obtained:

(NOTE.—The ceramic tests in this report were made by Mr. A. D. Potter, of this laboratory, who is in charge of this work. The tests are all made according to the methods recommended by the American Ceramic Society.)

Stiff Mud Series: Marked L

Test Piece	Cone "Down"	Temp at Which Piece Was Removed ° C	Dry Volume	Volume Burned	*Per Cent* Fire Shrinkage	*Per Cent* Porosity	Color
L 1	4	1210	37.9	28.2	25.6	45.6	White
					Av. 27.5	44.0	
L 2			37.9	26.75	29.4	42.5	
L 3	6	1250	37.9	24.9	34.3	38.7	White
					Av. 35.57	37.4	
L 4			37.6	23.75	36.85	36.2	
L 5	8	1290	37.6	22.4	40.45	32.6	White,
					Av. 40.67	32.1	Very
L 6			38.0	22.45	40.9	31.6	hard
L 7	12	1370	37.9	21.65	42.9	29.5	White,
					Av. 42.45	30.0	Steel
L 8			38.3	22.2	42.0	30.4	hard
L 9		1400	38.3	20.7	45.9	25.6	White
					Av. 46.05	25.2	
L 10			38.0	20.45	46.2	24.9	

Dry Pressed Series

L 1	4	1210	28.5	25.6	10.2	43.9	White,
					Av. 11.65	41.83	Very
L 2			28.1	24.4	13.1	39.75	hard
L 3	6	1250	28.2	22.75	18.6	36.7	White,
					Av. 20.15	35.4	Steel
L 4			28.3	22.15	21.7	34.1	hard
L 5	8	1290	26.4	19.5	26.2	28.2	White,
					Av. 26.5	28.4	Steel
L 6			27.2	19.9	26.8	28.6	hard
L 7	12	1370	30.2	17.7	41.4	27.1	White,
					Av. 42.0	26.6	Steel
L 8			31.7	18.2	42.6	26.1	hard
L 9		1400	32.6	17.65	45.8	21.5	White,
					Av. 45.8	20.85	Steel
L10			30.2	16.35	45.8	20.2	hard

The material has a melting point above 1,800 degrees Centigrade, Cone 33. The burned bricklets show fine "surface" cracks, but all the pieces are absolutely intact, and quite tough. The burnt material withstands sudden extensive changes in temperature without cracking. Some of the burned bricklets were heated to redness, dropped into water, and then put back into the red-hot furnace;

they withstand such treatment an indefinite number of times without cracking.

In comparison with many other kaolins, the Leakey kaolin has a high porosity and a high fire shrinkage. However, since kaolin is only from 30 to 50 per cent of the mixture used to make porcelain ware, it does not necessarily follow that this high porosity and fire shrinkage of one ingredient will affect the whole mixture. In fact, the successful use of Leakey kaolin in porcelain making is so well established as to make it almost unnecessary to consider this point especially. Yet it may not be amiss to point out that the kaolin from Gordon, Georgia, which is used extensively for white ware in the United States, has a porosity and fire shrinkage as large as the Leakey kaolin, and practically the same composition as the latter. This is seen from the following table of values taken from the *Transactions of the American Ceramic Society*, Vol. 19, page 253. These firing tests of the Gordon, Georgia, kaolin were made by the United States Bureau of Mines in 1917:

Temp. of drawing sample (° C.)	1210	1250	1290	1330	1370	1410
Per cent porosity	29.45	28.33	31.02	34.16	28.53	22.78
Fire shrinkage	36.01	33.05	32.88	31.10	36.05	40.40

Conflicting statements have been published concerning the plasticity of the Leakey kaolin. In Volume X of the *Transactions of the American Ceramic Society* there appears a statement by Arthur Mayer to the effect that this kaolin has a very high plasticity. This is confirmed by H. E. Ashley in United States Geological Survey Bulletin No. 388. But in *The Clays of Texas* (University of Texas Bulletin No. 102, page 83) Ries states that the plasticity of the Leakey kaolin is very low. These conflicting statements are probably due to the fact that Mayer had a sample of the kaolin which had been rendered soft and plastic by long contact with water, while Ries had a sample of the hard, flinty kaolin which had been ground dry only. In any case, it has been ascertained by us that even the flinty kaolin, when blunged or ground, wet, in a ball mill for a sufficient length of time, changes from a comparatively nonplastic material to one possessing an extremely high plasticity.

The most notable and valuable features of this kaolin are its extreme refractory nature and the fact that it will burn to an absolutely white color, provided the sample is not contaminated unduly with iron oxide. The latter can always be prevented by properly washing all impure material.

Physical Properties of the Fire Clay

The white sandy clay found in test wells Nos. 2, 3, 8, and 9, in the North Cave (sample F), has been tested to determine its possible value for ceramic purposes, and the following results obtained:

Test Piece No.	Temp. of Test-Cone	Temp. ° C.	Fire Shrinkage—Per Cent of Dry Volume	Per Cent Porosity	Hardness	Color
L 1	08	990	2.96	33.9	Med.	White with slight cream tint
L 2	08	990	3.7	33.4	Med.	White with slight cream tint
L 3	06	1030	3.97	34.0	Med.	White with slight cream tint
L 4	06	1030	4.18	33.6	Med.	White with slight cream tint
L 5	04	1070	3.7	33.4	Med.	White with slight cream tint
L 6	04	1070	3.98	33.8	Med.	White with slight cream tint
L 7	02	1110	4.21	33.8	Med.	White with slight cream tint
L 8	02	1110	4.2	33.8	Med.	White with slight cream tint
L 9	1	1150	5.16	33.0	Med.	White with slight cream tint
L10	1	1150	5.44	32.9	Med.	White with slight cream tint
L11	3	1190	6.9	31.3	Hard	White with slight cream tint
L12	3	1190	6.62	32.0	Hard	White with slight cream tint
L13	5	1230	7.7	30.6	Hard	White with slight cream tint
L14	5	1230	7.95	31.0	Hard	White with slight cream tint
L15	8	1290	9.85	29.2	Very hard	White with slight cream tint
L16	8	1290	9.85	29.0	Very hard	White with slight cream tint

Apparent specific gravity	2.47
Average water of plasticity	17.57 per cent of dry weight
Drying shrinkage	6.47 per cent
Softening temperature	1705 ° C. or 3100 ° F.—Cone 32 in a reducing atmosphere.

The softening point given above its undoubtedly somewhat lower than the true softening point, because the latter should be observed in an oxidizing atmosphere, while the furnace used in this work (an electric carbon resistance furnace) gave a reducing atmosphere which reduced the iron oxide present. Its true softening point is probably above 3,200 degrees Fahrenheit. Hence, the material is suitable for a good quality of fire brick or other refractory ware.

Test bricklets made up from stiff mud gave the following results on firing:

Even when burned to 1,280 degrees Centigrade this clay forms a very porous mass. However, the bricklets show absolutely no cracks, and the total shrinkage is quite low. It is quite possible that an ordinary or medium grade of porcelain ware can be made from this material by the mere addition of feldspar or some other fluxing material, but the material is not of sufficient value to be shipped any great distance.

When washed, this material readily separated from a large part of its sand, and hence increased its content of alumina (see analysis, sample C). This change naturally raises its melting point, which was found to be 1,732 degrees Centigrade or 3,150 degrees Fahrenheit in a reducing atmosphere (its true melting point is probably 3,250 degrees Fahrenheit, or even higher). However, washing does not lessen its iron content extensively, and hence it is not likely that pure kaolin can be prepared from this material.

Chemical Analysis of Kaolin Samples

Printed records present an analysis of Leakey kaolin made by the Texas Geological Survey, which is as follows:

	Per Cent
Loss on ignition	13.9
SiO_2	45.44
Al_2O_3	40.30
Fe_2O_3	0.54
CaO	trace
MgO	trace
Na_2O	0.38
K_2O	trace
TiO_2	trace

Another analysis made in the same laboratory is not presented here because it is so different from this and all others to lead me to believe that it was made on a sample other than this kaolin.

(NOTE.—The following analyses were made in the laboratory of The University of Texas, under my supervision, by Mr. J. E. Stullken, who is regularly employed here to do such work.)

The following samples have been analyzed, and specimens of these are submitted with this report:

Sample A: White, tallow-like mass with pseudo-crystalline fracture (from upper part of well No. 1).

Sample B: Dull white mass, interspersed with blue material, from upper part of well No. 1. The white and blue portions were separated, dry, as carefully as possible and analyzed separately.

Sample C: Hard flinty or shaly mass from middle part of No. 1.

Sample D: Same as C, except obtained from the lower part of well No. 1 and stained extensively with iron oxide.

Sample E: Material obtained by grinding Sample D, wet, in a ball mill, and washing by repeated decantations through a series of vessels. In this operation the kaolin was so finely divided as to float for a long time, while the iron oxide settled out relatively quickly.

Sample	A	B White Part	B Blue Part	C
Ignition loss	14.91	14.75	16.6	16.60
SiO_2	44.69	44.55	41.73	41.76
Al_2O_3	38.38	38.47	36.55	39.00
Fe_2O_3	0.94	1.13	5.12	0.37
CaO	0.42	0.55	0.66	0.80
MgO	none	none	.....	none
TiO_2	trace	trace	.....	none
Na_2O	1.53	1.26	.....	1.35
K_2O	0.10	none	.....	0.19
Total	100.97	100.71	.....	100.24
Per cent soluble salts in C				0.206

Two different portions of Sample D (Da and Db) were examined for their iron content when the iron oxide spots and the white portions were ground up together, and another portion (Dc), from which the red spots had been removed as far as possible by cutting out with a knife, was also examined. The results of these analyses were as follows:

Da	2.07 Per Cent Fe_2O_3
Db	1.76
Dc	0.66

A portion of the colored material (D) was ground fine in the dry state and then shaken up with water in a cylinder; the large upper portion formed on settling was practically white with a tint of cream color, while the smaller bottom layer plainly contained most of the iron. A sample from the upper part of the upper white

layer contained 0.53 per cent Fe_2O_3, and a sample from the middle portion of this white layer contained 0.61 per cent. This showed that washing serves to remove the iron oxide. Hence, a sample of D was subjected to fine grinding in the wet state and repeated washing by decantation as above described under Sample E; by this means over 80 per cent of the total mass was obtained in the form of a firm white kaolin with a superficial shade of pink (which color in washed kaolin is known to be of no harmful significance), and this material contained 0.2 per cent or less of Fe_2O_3. These results prove conclusively that this kaolin can be washed free even from this fine stain of iron oxide. Previous trials above mentioned have shown that the blue-stained material in the upper layers of the kaolin is still more easily removed by washing; hence, it follows that all portions of this kaolin can be washed into a first-class material.

A rational analysis of Sample A and of the white portion of Sample B, made according to the specifications of the American Ceramic Society, gave the following results:

Sample	A *Per Cent*	White Part of B *Per Cent*
Feldspar	3.12	4.09
Quartz	1.48	1.29
Clay substance	95.48	94.62

In this connection it was interesting to note that practically all of the clay substance is readily attacked by concentrated sulphuric acid—a fact that is of importance in connection with the question of making aluminum sulphate from this material.

The above results of the rational analysis show that the Leakey kaolin contains very little feldspar or quartz. The composition of the clay substance itself derived from these figures is the following:

SiO_2	44.15
Al_2O_3	40.15
H_2O	15.8
Total	100.10

This composition approaches more nearly that of Indianaite than that of any other kaolin-like mineral.

Chemical Analysis of Fire Clay

The material found in the southwest quadrant of the North Cave has been shown above to be a fair grade of fire clay, and hence is so designated in this report. Samples of this material are submitted with this report under the following designations:

Sample F: White clay from test wells Nos. 2, 8, and 9.

Sample H: From test well No. 12. Its analysis (see below) shows it to be a better fire clay than Sample F.

Sample G: (Not submitted.) This was obtained by grinding a portion of Sample F, wet, in a ball mill for several hours and then subjecting it to washing by decantation through a series of vessels. The sand settled readily. The floating material obtained was about 50 per cent of the total. Its analysis (see below) shows it to be practically identical with H.

Sample K: (Not submitted.) Much inferior to Samples F, G, and H, and is practically worthless.

The following table presents the results we obtained by analyzing Samples F, G, H, and K:

Sample	F from No 8	F from No. 2	G	H	K
Ignition loss	7.20	7.42		10.21	6.60
SiO_2	70.38	70.83	55.65	57.42	58.83
Al_2O_3	18.48	16.39	29.95	27.45	17.28
Fe_2O_3	2.07	1.91	1.43	2.12	13.27
CaO	1.12	0.96		0.80	0.53
MgO				0.22	0.19
TiO_2				1.50	1.20
Alkali oxides (as Na_2O)	1.87	1.51		1.43	1.41
Total	101.12	99.01		101.15	99.37

Probable Value and Use of the Kaolin in Eastern Market, and Suggestions for Mining and Manufacture

The properties and chemical composition of this kaolin from Section 71, which were set forth above, and the fact that the material can be washed so as to be free from all impurities and stains even, and to be of a uniform texture; all these indicate that a uniformly high grade of material can be produced. The high value of this material has, furthermore, been attested by the report of Mr. A. Mayer, which appeared in 1908 in Volume X of the *Transactions of the American Ceramic Society*. It is further attested by a letter from the Robineau Pottery, Syracuse, N. Y., submitted with this report. As a further testimonial to the value of the Leakey kaolin, a letter from Mr. Thomas E. Anderson, Manager of the Pope-Gosser China Company, of Coshocton, Ohio, is also submitted herewith. This letter shows that a washed product, free from discolorations, would be worth $50 a ton, f. o. b. Camp Wood, Texas.

Besides its use for high-grade porcelain, the material should command a high price for (a) a white paint pigment, (b) paper sizing, and (c) alum and aluminum sulphate manufacture.

On account of the high cost of freight to the eastern market (for instance, about $15 a ton from Uvalde to Columbus, Ohio), it is

useless to contemplate putting it out except as a uniformly high-grade material. This can be accomplished by the installation of a washing establishment at Camp Wood. All high-grade kaolins in England, Germany, North Carolina, Georgia, etc., are washed before they are offered for sale, and this Leakey kaolin is easily washed, probably at a lesser cost than that at which many others are washed. The cost of washing in England and in North Carolina has been estimated to be $2 to $3 per ton. The fact that land and water are available in sufficient amount at low cost at Camp Wood, and that the dry climate will help to hasten the drying of the washed "cake," renders it likely that the cost of washing this kaolin will not exceed $4 a ton. The cost of mining on Section 71 is very much less than the cost of mining high-grade kaolin elsewhere. The mining will be all open-pit work, and the material is easily worked with pick and shovel. The mining of kailin in North Carolina, for instance, is very troublesome, the material being interspersed with rocks. The veins must be followed carefully and timbered, none none of which has to be done here. The trucking of the Leakey kaolin has to contend with the distance only, because the road is good and runs down hill most of the way, while the hauld down and through the mountains of North Carolina is very hard and troublesome. Hence, I am of the opinion that the cost of mining and hauling the kaolin from Section 71 to Camp Wood will not be greater—perhaps even less—than the cost of mining and hauling kaolin elsewhere.

The possibility of washing this kaolin to a uniformly high-grade material which will command a high price leads me to believe that it probably can be shipped to the eastern market and sold at a considerable profit, in spite of the long freight haul and trucking cost.

The following considerations may give a forecast of the cost of mining and hauling the kaolin to Camp Wood:

Cost of hauling:

Using five-ton trucks, we can make two trips, delivering 10 tons a day or 300 tons a month.

Truck driver	$150.00 per month
Maintenance and replacement cost of truck	150.00 per month
Total	$300.00 per month, or $1.00 a ton for hauling

Cost of mining:

1 laborer can open 14 cu. yds. a day with a pick.
1 laborer can shovel into a wheelbarrow 17.2 cu. yds. a day.
1 laborer can move with a wheelbarrow 40 tons a day a distance of 65 to 75 yards.

Hence, 6 laborers can together mine and deliver 40 tons a day to the elevator. At $3 a day per man, this amounts to 50 cents a ton.

Allowing 25 cents per ton for operation of the elevator, and doubling this total cost to allow for all extra work such as removing cover, draining or pumping rain water out of pit, etc., makes the total cost of mining $1.50 per ton. Hence, $2.50 is the cost per ton, delivered at Camp Wood. Adding $1 for overhead expense, and $4 per ton for washing, gives as total cost, f. o. b. Camp Wood, $7.50 per ton.

The mining system contemplated above consists of the removal of the cover from a portion of the kaolin block, say, over an area of 75 feet by 100 feet, beginning at one end of the block and taking up the kaolin in horizontal slices about 4 to 6 feet thick over this area. The kaolin wall on one side and the rock wall on the second will easily maintain their shape. The elevator should be put up next to the rock wall, so that the trucks may be loaded by dumping the elevator buckets through a chute directly into the trucks. The sand sides may have to be graded to prevent their collapsing. The inflow of rain water should be prevented by building slight ridges or dams around the top edges, and a pump may have to be installed to drain the pit after a rain. It may even pay to put up a movable roof over the pit. Special attention should be given to keeping the kaolin underneath as clean as possible.

The price that may be obtained in the eastern market cannot be reliably indicated at present. The value of $50 stated in the letter above quoted from Mr. Anderson, of the Pope-Gosser China Company, is probably unusual. Inquiry of the United States Geological Survey has revealed the following prices:

	Per Ton	
At Georgia mines f. o. b.:		
Crude	$ 8.00 to $10.00	
Washed	10.00 to 12.00	
Powdered	15.00 to 20.00	bags extra
At Virginia mines:		
Powdered	$15.00 to $20.00	
At sea ports:		
Domestic lump	$10.00 to $20.00	
Powdered	25.00 to 30.00	
Imported lump	15.00 to 25.00	
Powdered	35.00 to 45.00	

Hamil and Gillespie, Importers, at 240 Front Street, New York, say: "We have gotten potting clay which we have been able to sell for as little as $16 per ton, f. o. b. at Atlantic seaports. The values run up to $25 at the same points."

Moore and Munger. 29 Broadway, New York, write: "Everything depends upon quality. We are selling washed Georgia kaolins at $7.50, and making a profit. We are importing English china clay, selling same at prices approximately $15 per ton, including a profit."

These and other price indications lead me to believe a fine quality of kaolin, which I believe the Leakey kaolin to be, will bring, washed, a price of $40, delivered at points in Ohio. The latter is practically the center of porcelain manufacture in the United States. The rapid progress that our fine china industry has made in the last few years, and the pride taken in producing "all-American" products, will create a demand for the best material available. A higher price than $40 for the washed material, delivered, may be obtained if the material demonstrates its high quality. Certain it is that it cannot be produced, washed, and delivered for less than $30 a ton, because, with the high freight rates now prevailing, the margin of profit would be too small to justify the venture.

Since such relatively high prices cannot be obtained except for a uniformly high quality of product, I have made an attempt to get a quotation by submitting sample lots. All purchasers and dealers ask for five-pound samples for trial. Such requests were made by the following firms:

Whitaker, Clark and Daniels, Inc. 250 Front St., New York.	Minerals, colors, chemicals.
National Sales Co. 31 East 13th St., Cincinnati, Ohio.	Minerals and refractory materials.
Western Paper Makers Chemical Co. Kalamazoo, Mich.	Manufacturing chemists, miners, importers.
Hamill and Gillespie 240 Front St., New York.	Importers.
Product Sales Co., Mr. Henry N. Hanna, 206 Water St., Baltimore, Md.	
Moore and Munger 29 Broadway, New York.	Clays.
The Guernseyware Co. Cambridge, Ohio.	Manufacturers of high-fired products.

I did not respond to these requests, because I believe it to be highly essential that a lot of 100 to 200 pounds of washed kaolin, of uniformly high and tested quality, be prepared and then sent out as samples. The preparation of this sample should be done with due regard to the water eventually to be used, and the whole operation will naturally be a test of the industrial value.

An idea of the equipment necessary for this work may be gained by reading Bulletin 53 of the United States Bureau of Mines, entitled "Mining and Treating of Feldspar and Kaolin in the Appalachian Region," by A. S. Watts. Only samples thus prepared and carefully tested should be sent out, because the success or failure will depend upon the first samples. I strongly urge that this preparation of a sample lot and ascertaining of price be done.

However, if the material can be sold in the eastern market at any profit, it is safe to say that a royalty of $2.50 per ton for the material in the ground is little enough to ask.

In the absence of a positive proof that the material can be sold at a profit in the eastern market, I prefer to use the following means of marketing it as a basis for estimating the value of the deposit.

Fire brick and other refractories of specially high quality are not made in Texas at present because the raw material is lacking. Section 71 contains all the necessary material for making anything from the most refractory material down to a "high quality of second class" (so called). By the latter I mean a brick that will withstand between 3,100 and 3,200 degrees Fahrenheit. I doubt that the best fire brick now made in Texas will stand up quite as well as this lowest grade made from Section 71 would do. Furthermore, a fine white face brick could be made. These materials would find a ready market in Texas and have the advantages of freight. The nearest points at which first-class fire brick are made are at St. Louis and at Denver. Evans Howard fire brick can be bought in St. Louis for $25 a thousand, while before the war they cost $52 laid down in Austin. This shows what an enormous advantage freight rates will be to the local manufacturer.

Without attempting to put a value on the pure white sand and on the fire clay found on Section 71, I would say that the kaolin is worth at least $2.50, if thus used together with these other materials to make refractories or white ornamental face tile and brick. Lignite is found in large amounts in Atascosa County, shipable over the S. A. N. R. R. to Camp Wood, and the whole manufacture can be carried on there very economically and successfully.

These considerations lead me to say that the deposits in Section 71 are worth $300,000, and that $250,000 would be a very low price. I am of the opinion that the kaolin is really too fine to be used up in making fire brick, etc., but I point out this way of utilizing it because I feel sure that this procedure would pay, and that, for this purpose, the deposits are worth the amount stated.

Kaolin on Section 6, Block F, G. N. and S. A. R. R. Survey

I have made two visits to the localities in this section where kaolin is visible. One of these points is the bank of a draw and the others are pits dug in prospecting for kaolin. None of the places appear to be thicker than eight or ten feet, and they are extensively stained with iron oxide or mixed with sand. Concerning the horizontal extent of these deposits I know nothing definite, but it is questionable that it is great. In mining, the material is almost certain to become badly contaminated, but it probably can be purified thoroughly by washing.

The amount in sight is large enough to be worth considering in connection with the development of the deposit on Section 71, but not enough to consider it as a separate project. The quality of the

washed material will be undoubtedly the same as of that on Section 71.

Other Special Clays

There are a number of types of clay which find special uses and command a higher price than the ordinary clays. The most important of these is the material known as bentonite or wilkinite. This is not a definite mineral form, but is merely a special type of clay. Davis and Vacher[1] state that bentonite is a mixture of the two minerals, montmorillonite (a hydrated alumino-silicate of either calcium or magnesium) and beidellite (a hydrated aluminum trisilicate). With these minerals are associated impurities such as quartz, feldspar, mica, etc. All gritty impurities must be removed before bentonite can be marketed. The most prominent physical property of a true bentonite is its tendency to absorb large proportions of water and swell to much greater volumes. This swollen material has a jelly-like consistency. The extent of such swelling affords a rough means of comparing and classifying bentonites. A chemical analysis does not have much value in the testing of such a material, its value being judged almost entirely by the testing of the properties which distinguish it. Bentonite is thought to result from the weathering and devitrification of a volcanic ash or similar material, and most known deposits are of a primary character.

The value of bentonite is determined by its colloidal properties. The soapy feel of the gelatinous mass formed when it is wet caused it to be known as "mineral soap" when this property was first observed. It has a considerable tendency to absorb grease and dirt, and thus it resembles soap in effect as well as in appearance. It is said to have been actually used as a cleansing agent by the early settlers of the West.

The uses of bentonite are as follows:

For increasing the plasticity of pottery mixtures
As suspension agent in ceramic glazes;
As plastic bonding agent in:
graphite crucibles,
pencil leads,
electric and chemical porcelain,
abrasive wheels;

[1]C. W. Davis and H. C. Vacher. U. S. Bureau of Mines Tech. Paper 438 (1928).

In cements to produce closer, more impervious texture;
As filler and cleansing agent in soaps and detergents;
As absorbent for coloring matter; in this use it replaces fuller's earth, and for certain purposes it has been found to give better results than real fuller's earth;
As a filler in paper; its use in this field is limited by the fact that bentonite is seldom pure white;
As a water softener; it has been found that, when partially dehydrated, bentonite possesses the property of a "base-exchanger," like zeolite; the calcium and magnesium in the bentonite may be replaced by sodium from common salt and the sodium compound thus formed may be used to remove the calcium and magnesium salts from hard waters.

Bentonite has been reported in Colorado and Potter counties, in Texas. No deposit is known to have been investigated to a sufficient extent to establish whether or not a commercial possibility for bentonite exists within the State. One sample of clay described as bentonite is on record as having been analyzed by this laboratory, but no tests seem to have been made to prove that the material had the properties which would mark it as a bentonite. The results of this analysis are recorded in Part II, as sample No. C1156.

The practice of using a "mud-laden fluid" in the drilling of wells by the rotary method has given rise to a demand for clay adapted to this use. It is common practice to mix a quantity of any naturally occurring clay with the water used as circulating fluid in such drilling operations, for the following purposes:

To plaster up the sides of the hole, and thus reduce caving, infiltration of water, gas, or oil from the strata which have been passed, and loss of drilling fluid into porous formations;
To increase the viscosity and specific gravity of the circulating fluid, and thus increase its effectiveness in carrying the cuttings up from the hole;
To furnish a lubricating medium between the rotating drill stem and the walls of the hole.

Clays found near the well or encountered in the drilling may serve these purposes well, but such clays are seldom uniform, and may introduce large amounts of gritty and abrasive substances such as sand or feldspar grains into the drilling water. There are accordingly offered on the market specially prepared clays under

a variety of trade names. These are either naturally pure or artificially purified clays. Their necessary properties are a high proportion of finely divided or colloidal matter and a freedom from all gritty particles.

Fuller's Earth

Fuller's earth is a sandy clay of such porous structure as to possess the property of absorbing certain substances. All clayey earths have this property to some degree. Fuller's earth merely possesses the property to such a degree as to make it usable in commercial processes. The only way of testing an earth to determine its value as a fuller's earth is to make an experimental demonstration of its absorptive capacity. The earths commonly employed possess certain chemical and physical properties which will be enumerated here, though it is not to be understood that these properties are necessarily connected in any way with the absorptive qualities. These properties are:

High magnesia content;
Low plasticity;
Low apparent specific gravity, due to porosity;
Acid reaction, due, according to Parsons[1], not to the presence of any acid, but to the tendency of the earth to adsorb basic ions.

The test of a fuller's earth is merely a comparison of its bleaching action with that of a standard earth of established commercial value. The amount of the unknown earth required to remove a certain amount of coloring matter is determined and compared with the amount of the standard earth required to produce the same effect.

Fuller's earth is used to remove coloring matter and other finely divided matter suspended in aqueous and oily solutions, and thus serves to bleach and clarify such liquids. Its greatest commercial application, at least in this State, is in the removal of tarry matter from petroleum products. It can also be used for water solutions and for vegetable oils such as cottonseed oil. A fuller's earth which will give satisfactory results for one class of liquids may fail completely to treat satisfactorily another class, and a test of a sample of unknown value should include trials with all classes.

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[1]Charles L. Parsons, U. S. Bureau of Mines Bull. 71 (1913).

Fuller's earth is usually, though not always, heated to some extent before use. In oil-refining practice it is heated in a rotary furnace to low red heat, and after it has absorbed its capacity of coloring matter it is washed free from adhering oil and again roasted. This second roasting drives off the absorbed matter and restores the effectiveness of the earth. Some is lost, of course, in each operation, and must be replaced by the addition of the necessary quantity of new fuller's earth. The clarifying operation is carried out in a tall column packed with the earth, through which the raw liquid percolates. The earth must be pulverized and screened to separate it into uniform sizes. The sizes in general use are as follows: Fifteen to 30-mesh, 30 to 60-mesh, and 60 to 80-mesh.

There are proven deposits of fuller's earth in Texas, in Bexar, Walker, Fayette, and Washington counties. Samples from Anderson County have been examined by this laboratory (No. C612) and found to possess satisfactory absorptive properties, but the extent of this deposit is not known. Other deposits undoubtedly do exist within the State. There are plants now producing fuller's earth near San Antonio, in Bexar County, and at Riverside, in Walker County. Other plants which have operated in the past have ceased to exist, demonstrating the difficulties encountered in this line. Fuller's earth does not command a very high price—the latest quotations, December, 1930, give the price as $15 per ton, in sacks—and there is thus much difficulty in producing it at a profit. A paying deposit must contain earth of acceptable uniform quality, in such condition and quantity that it can be removed and prepared for market very cheaply, and must be located in close proximity to a market which is capable of utilizing the output.

Feldspar

Feldspar, as discussed in Chapter II, is the parent substance to clay. It is an alkaline alumino-silicate, which decomposes on weathering and devitrification into soluble salts of the alkaline constituent and the insoluble alumino-silicic acid which is the basic constituent of clay. In addition to being the base of clay formation, feldspar is important in clay technology through its use, as such, in pottery and porcelain mixes. Its function in such mixes is as a cementing agent and solvent by virtue of its fluxing tenden-

cies. For porcelain purposes, feldspar must be tested for color and deformation temperature. If these tests show satisfactory properties, the finely ground feldspar must be mixed with quartz and plastic clay or kaolin in proper proportions, and fired. The fired test pieces are examined to determine whether they have the pure white color, translucency, vitrification range, and shrinkage which are required for this purpose. Feldspars are known to exist in Texas in the central mineral region (Llano County, Burnet County, etc.), and in the mountainous trans-Pecos regions, but sufficient information has never been obtained to prove the presence of any commercial deposits.

Diatomaceous Earth

This type of earth is also known as infusorial earth or kieselguhr. It has been formed by the silicification of the remains of minute organisms called diatoms. The skeletons of the diatoms may be plainly seen when a sample of this earth is examined under the microscope, and such an examination is the only way of determining whether or not a substance is a diatomaceous earth. The chemical analysis of such an earth shows it to be largely—usually between 80 and 90 per cent—silica, the remainder being clayey matter. Because of the skeleton structure, the material is very porous, and consequently very light in weight. The specific gravity of a good quality diatomaceous earth is as low as 0.24 (that is, about one-fourth as heavy as water). It is a poor conductor of heat, sound, and electricity, and hence can be used as an insulator. Its other uses are:

As a clarifying and filtering agent; it is sometimes added to liquids which tend to clog filters; it builds up a thin, porous layer on the surface of the filter cloth and prevents the small suspended particles from getting into and clogging the pores of the cloth;

As a decolorizing agent or as a gas absorbent; it can be used for these purposes by virtue of the fact that it possesses to some extent the absorptive qualities of a fuller's earth;

As a filler in sealing-wax, match heads, plastic compositions, insulators, etc.;

As a light abrasive in polishing powders;

As a dispersion medium for catalysts;

As an absorbent for nitroglycerin, forming dynamite.

PART II

Data from "THE CLAYS OF TEXAS," by Heinrich Ries

University of Texas Bulletin No. 102, 1908

The following pages contain condensed tabulations of the data on physical tests and chemical analyses printed in Dr. Ries' bulletin. Following these tables are found descriptions of the individual samples giving the locations from which these samples were obtained and the more important observations made with regard to them. All facts contained herein are taken from Dr. Ries's report and are to be understood to have applied at the time he made this investigation (1903) and may have been somewhat modified since that time.

Note: In all of the following tables all numerical data are given only to the first decimal place. In the original bulletin many of these were printed with a second decimal place, but since in fact this second place is almost invariably of no significance, and its retention is not only troublesome but apt to be misleading, it is dispensed with throughout.

Following these tables are tables of the chemical analyses and physical tests made more recently, together with descriptions of the samples thus analysed or tested, and finally lists of all samples arranged, first according to counties, and then according to classes of clays.

Abbreviations used in these tables are:

C=Coarse	G=Good	Sl=Slow
F=Fine	H=High	V=Very
Fa=Fair	L=Low	vis=Viscous
Fst=Fast	M=Medium	vit=Vitrified

Discussion of samples described in Ries' Bulletin No. 102—

801. From M. Butler's brick yard, Austin, Travis County. A red, gritty, calcareous clay, which burns buff and makes a good common brick when molded by the soft mud method.

802, 803, 804, and 805. Shales associated with coal from near Laredo, Webb County. 802 and 803 are shales found below and between coal seams near Mineia, 804 is shale found below lower coal seam at Cannel, and 805 is a weathered sample from the same source as 804. All are of good plasticity and high drying shrinkage. They burn to a buff color, with the exception of the weathered sample, which has a light color at lower temperatures and brown color above cone 1. All are suitable to the manufacture of buff brick, preferably by the dry press process.

806. From brick yard at Laredo, Webb County. A sandy calcareous clay used for making common brick by the soft mud process. It burns first to a buff, which at cone 1 takes a brownish shade.

807. From clay pit at Saspamco, Wilson County. A speckled, shaly clay used for the manufacture of sewer pipe. It is very plastic and sticky when wet, burns buff up to cone 5, at which point it turns to gray. A fairly good pottery clay.

808. From 2½ miles southwest of Elmendorf, Bexar County. A light brown clay used for pottery and stoneware. Similar to Sample 807, but more homogeneous and slightly more refractory. It burns buff up to cone 9, and by cone 14 it has turned gray and swollen a little.

809. From clay pit a short distance east of Calaveras, Wilson County. A calcareous, silty river clay used in the manufacture of dry press common brick. The raw clay is brown in color and burns to a buff.

810. From bank of Calaveras Creek, Calaveras, Wilson County. A brown clay shale which burns buff. It has tender drying properties for which reason it is best adapted to the dry press process, and would be suitable for buff press brick. It is similar to the Saspamco and Elmendorf clays (807 and 808) but is less refractory and more highly contaminated with iron particles and streaks.

811. From clay pit 3½ miles east of San Antonio, Bexar County. A red burning clay which can be worked only by dress press methods since the mud bricklets cracked, swelled and blistered in drying and burning. It contains 0.92% soluble salts. It may be made into good bricks by the dry press method.

813. From near Seguin, Guadalupe County. A highly calcareous clay used for common brick. It burns to a dirty gray-brown color.

814. From Olsen's Lignite mine, Rockdale, Milam County. A gray, dense, shaly clay which burns buff shading to gray at high temperatures. It has fair refractory qualities and is used to some extent as fire clay. It might be used for buff brick or even for stoneware.

815. From a short distance south of Adkins, Bexar County. A brown, sandy, fairly plastic clay of moderate refractoriness. It could be used for No. 2 firebrick or for wet-mud common brick. It burns buff to gray.

816 and 817. From the bank of the Guadalupe river near Gonzales, Gonzales County. Upper and lower layers from this deposit are represented by these two samples. The deposit is a calcareous river silt, the upper layer being green and the lower brown. The top layer is more plastic, but has tender drying and burning properties. The lower is less plastic

but more plentiful and has better drying and burning strength. A mixture of the two is used to advantage in the manufacture of common brick. Both clays burn buff.

818. From 6 miles southeast of Gonzales, Gonzales County. A sandy grayish-brown clay of low plasticty and high air shrinkage. Its strength is low, and it has very tender properties, making it of very doubtful value. It burns buff and begins to become viscous and to blister at cone 9.

819 and 820. From ¼ mile northeast of the source of sample 818. A dense fine-grained soapy-looking clay, of low plasticity and tender drying properties. It would burn white but for the contamination of limonite in all the crevices. This might be partly removed on washing, but it is doubtful that a high grade material approximating a kaolin could be thus produced.

821. From terrace bordering Buffalo Bayou, near Harrisburg, Harris County. A sandy alluvial loam used for making common wet-mud bricks and not suitable for any other purpose. It has low plasticity and tensile strength, but dries well. It burns to a brown color.

823. From same source as Sample 821. This sample is taken from the stratum below the one represented by Sample 821. The chemical analyses of the two strata show practically identical composition, but the physical properties are quite different. This lower layer is much less gritty, more plastic, has higher tensile strength but very tender drying properties. It might be used for a dry-press brick.

824 and 826. From clay pits near Houston, Harris County. These are samples of reddish-brown loamy clays taken from different parts of the same deposit. No. 826 is more sandy than No. 824, slakes faster and shrinks less in drying, but the two are essentially somewhat similar. Both are well adapted to the making of dry-press common brick but not to any other ware.

825. From near Houston, Harris County. A sandy brown-red burning clay, useful for making common brick. It cannot be worked dry-press.

826. See 824.

827. From lignite shaft 3½ miles north of Rockdale, Milam County. This sample is from a clay stratum underlying a lignite vein,[1] the depth being 58 feet. It is a dark gray clay which burns buff, and must be burned carefully because of the organic matter present. It might be used for brick, for which purpose dry-pressing would be the best method.

829. From Vogel's mine, Rockdale, Milam County. This clay is in a bed about 4 feet thick and can be mined in connection with the lignite which overlies it. It is dark in color due to the organic matter present. It could be used for No. 2 fire brick or for buff burning building brick, or even for stoneware. For all these purposes, care in burning is necessary because of the organic matter. The working qualities of the clay are improved by weathering.

830. From surface near Vogel's mine, Rockdale, Milam County. A sandy red-burning clay used for dry-pressed brick.

831. From southwest of Lena, Fayette County. This was a "so-called" kaolin, but the tests and analyses show that it could not be classed as a kaolin.

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[1]It should be noted that, while clays associated with coal seams are frequently found to be of a refractory nature, those found associated with lignite beds do not often show this tendency.

It was white in color, but had heavy limonite stains on the joint and fracture surfaces. It was so lean, and cracked so badly on drying, that only dry-press bricklets could be tested. The bricklets burned steel hard at cone 9 and fused to a clear class at cone 27. All of the burned samples showed small black specks.

832. About the same location as Sample 831. This sample was a clayey sand known locally as "pumice dust," which name was of course inaccurate. Its tests showed it to offer no possibilities as a ceramic material.

833 West of Leakey, Real County. This was a sample of the Leakey kaolin described and discussed at length in Chapter V of this bulletin.

834. From 2 miles northwest of Beaumont, Jefferson County. A yellowish-brown clay which burns to a brown and is used for common pressed brick. Wet molded bricklets showed a tendency to warp and crack on drying.

835. From 1½ miles south of Corsicana, Navarro County. A yellow-brown clay burning to a red brown. It is difficult to burn due to the high organic content, and has some tendency to crack on burning. It is manufactured into brick by the dry-press process and burned at low temperatures.

836 and 837. From West Dallas, Dallas County. These samples are from the upper and lower strata of the same deposit. The upper clay (836) is red and the lower (837) blue. Both are clays of the Eagle Ford series and are used in the manufacture of a good grade of building brick.

838. From West Dallas, Dallas County. A blue shale from another clay pit, also representing the Eagle Ford clays.

839 and 840. From clay pit at Ferris, Ellis County. The first is a sample of the upper red clay and the second of the lower blue shale of the Eagle Ford series as found at this point and is used in the manufacture of pressed brick.

841. From 8 miles west of Dallas, Dallas County. Another sample of Eagle Ford clay.

842, 843 and 844. One mile south of Denton, Denton County. These samples were taken respectively from the upper, middle, and lower layers of a clay bank. The upper is a blue clay, the middle a mottled yellow, and the lower a gray to black clay. None of them show an excessive air shrinkage and the tensile strength of all is good. They all burn to a good dense body without high fire shrinkage, but No. 844 shows a tendency to warp and split on burning. No. 842 burns to a hard body at cone 05, blisters somewhat at cone 9 and showed signs of viscosity at cone 12. No. 843 might be expected to burn to a deep color judging by the amount of iron present, but this is found to be not evenly distributed, but concentrated in patches which, on burning, produce dark fused spots on a buff ground. Otherwise they are all buff-burning, their colors deepening above cone 05.

845. From 2 miles east of Denton, Denton County. A buff-burning clay of fair refractoriness, used for pottery and stoneware.

846. From near Thurber, Erath County. A brown-burning clay used in pressed brick manufacture. Its high organic content necessitates great care in burning.

848. From near Thurber, Erath County. A vitrifiable brick clay used for making face bricks by the dry-press process and paving bricks by the

stiff mud process. It burns to a brown color, and produces a dense body at cone 1.

849 and 850. From Malakoff, Henderson County. Both samples are fire clay, the lower black clay being slightly more refractory than the upper blue clay. No. 849 tended to crack in drying unless dried very slowly, and burned to a light color. No. 850 dried better and burned to a buff color. These clays are used for pressed brick.

851 and 852. From fire clay pit at Athens, Henderson County. No. 851 is a sample of the main fire clay and No. 852 of the slightly more sandy clay which overlies it. No. 851 is shown to be a good quality fire clay and is used in the manufacture of fire brick, when molded by the stiff mud method. No. 852 has slightly lower refractoriness and is used in small proportions mixed with the better material.

853. From pit in west edge of town, Athens, Henderson County. This is a hard, laminated, grayish-brown clay which burns to a whitish to buff shade. It has been used as a constituent of a mixture for stoneware.

854. From 2½ miles west of Athens, Henderson County. This is a blackish clay burning to gray-white and is used as the principal constituent of a mixture for the manufacture of glazed stoneware. It has fair refractory properties and might be used for fire brick or buff pressed brick.

855. From 6 miles south of Nacogdoches, Nacogdoches County. A dark brown, finely gritty clay, burning to a good dense body of a buff to gray color. It has been used for common stoneware, but might also be used for buff pressed brick or for terra cotta. It is not sufficiently refractory for fire brick.

856. From 2 miles south of Rusk, Cherokee County. A buff burning clay of Tertiary age, the raw material being of a dark brown color and hard shaley nature. It has been used for buff building brick and is quite susceptible to flashing. It lies under a layer of red burning clay described below (857).

857. Same as 856. This upper layer of red burning clay is mixed with the lower layer in the making of common building brick.

858. On state line near Texarkana, Bowie County. A gray fine textured clay with fine limonite stains. It dries and burns well, but shows some tendency to blister when burned to cone 12. It can be used for stoneware or for building brick. It burns buff to gray.

860. Close to New Boston, Bowie County. A dense shaley clay which burns to a brown color. It has high air shrinkage and cracks badly on drying unless dried with great care. It is used for making red pressed brick.

861. From 7 miles south of New Boston, Bowie County. This is a hard tough black clay which bleaches out on weathering and burns buff. It has good refractory properties.

863. From Greenville, Hunt County. A grayish-brown, shaley clay which burns light brown up to cone 3, above which it darkens until it is chocolate at cone 9. It might be used for stiff mud or dry pressed brick.

865. From near Winnsboro, Wood County. A coarse, sandy loam, which burns brown. It may be made into building brick but requires comparatively high temperatures for burning. It is too sandy for dry-pressing but works well by the wet process.

866. From near Cedar Bayou, Chambers County. A sandy alluvial clay, which may be made into good common brick by the stiff mud or soft mud processes. It burns to a dull red color.

869. From northeast of Sulphur Springs, Hopkins County. This is a bluish shale which burns brown. It contains many limonite crusts and concretions which produce fused spots in the burned brick unless great care is taken to grind them fine. The tempered clay has a high drying shrinkage and consequently will work better by the dry-press process.

870. From 6 miles southeast of Sulphur Springs, Hopkins County. This is a fair grade of fire clay which has been used both for fire brick and for light colored press brick.

871. From near San Angelo, Tom Green County. This is a red, easily fusible clay which burns to a dense red-brown body at cone 05. Its fusibility is due to the presence of soda and potash, and it might be used as a slip clay.

872a. From Property of H. B. Pope, Winnsboro, Wood County. A light gray granular clay with mottlings of limonite.

8772b. From 5 miles west of Winnsboro, Wood County. A brown clay with tender drying properties. It is used mixed with the clay represented by sample No. 872a in the manufacture of stoneware.

873. From near Brenham, Washington County. An easily fusible clay which forms a very sticky mass of high air shrinkage when molded wet, and thus would best be dry-pressed if brick or tile manufacture were attempted. It might be used as a slip clay because of its fusibility.

874. From near Cornersville, Wood County. A light gray shaley clay used for stoneware.

874a. From 2 miles southwest of Cornersville, Wood County. This is a light brown clay which burns to a dark buff. It is used in the manufacture of stoneware, mixed with the gray clay represented by sample No. 874.

875. From a brick plant clay bank at Sherman, Grayson County. A dense shaley clay of the Eagle Ford series, containing a considerable amount of organic matter.

876. From near Austin, Travis County. Another Eagle Ford clay, also very high in organic matter.

877. From near Terlingua, Brewster County. A buff burning, calcareous clay of easy fusibility.

878. From 14 miles west of Graham, Young County. A gray clay which burns to a brown, dense body.

879. From 16 miles west of Graham, Young County. A gray clay similar to the above which burns to a hard body at comparatively low temperatures.

880. From near Graham, Young County. A gray clay which burns buff to yellow and which, due to its easy vitrification, might be used for paving brick.

881. From property of U. R. Shine, Hortense, Polk County. A pinkish-brown sandy clay which burns to a gray brown color and a dense body. It might be used for common brick.

901, 902 and 903. From right bank of Old Caney Creek, a few miles north of Wharton, Wharton County. No. 901 represents an upper layer, No. 902 a lower, and No. 903 a mixture of the two as was being used for

brick manufacture. The clays are sandy and calcareous and would be of little use except for common brick.

904. From near junction of T. & N. O. and M. K. & T. R. R. at Colmesneil, Tyler County. A red, very sandy clay. It burns brown but does not become hard until very high temperatures are reached. This is due to the high silica content, and it is not any thing like a fire brick clay either in refractoriness or other properties. It is used for common brick.

905 and 906. From near Longview, Gregg County. No. 905 is a mixed sample of two upper strata, and No. 906 is from a stratum underlying these two. No. 905 is red and burns brown No. 906 is brown and burns buff. Both have high plasticity and high fire shrinkage, making drying of wet molded bricks difficult so that dry press methods would be best for brick making.

907. From 1 mile west of Marshall, Harrison County. A brownish-red sandy clay which burns brown. It is used for stiff mud building brick.

908. From 2 miles from Calvert, Robertson County. A white clay of silty character. It burns to a gray color and does not get steel hard until cone 9 is reached. Its use is suggested for putting a dull white slip glaze on terra cotta.

909. From 1 mile west of Giddings, Lee County. This sample is a mixture used for the making of common brick. A white plastic clay is mixed with the yellow sandy soil which covers it. The sandy soil overcomes the troubles caused by the excessive shrinkage of the clay.

910. From 2 miles northwest of D'Hanis, Medina County. A light brown calcareous clay, used for making common soft mud brick.

911. From 1 mile west of Taylor, Williamson County. A bluish marl which burns buff to a porous body. It is used for dry-press common brick and stiff mud paving brick.

913. From 6 miles east of Denton, Denton County. A tough gray clay of high plasticity which burns to deep buff and is used for stoneware.

914 and 915. These samples are of two brick mixtures of Eagle Ford clays used at Paris, Lamar County.

918 and 919. From 2 miles east of Belton, Bell County. No. 918 is a calcareous clay, and No. 919 a mixture of the same clay with a less calcareous clay. This latter mixture is used for brick making.

920. From near Detroit, Red River County. A gritty loamy brick clay with high air shrinkage. It would make common brick, the dry-press method being best for forming it for this purpose.

921. A brick mixture made from Eagle Ford clays at Cooper, Delta County.

922. From ½ mile west of Cleburne, Johnson County. A sandy loamy clay used for common brick. Because of the sandy character it must be molded wet and must be burned to a rather high temperature in order to produce a dense product.

923. From 2½ miles south of Milano Junction, Milam County. A white shaley clay with some limonite. It has good refractory properties and could probably be used in the manufacture of refractory ware.

925. From 1¼ miles east of Strumberg, Bexar County. A white clay used for stoneware.

926. From 1¼ miles south of Adkins, Bexar County. A white clay of fairly high refractoriness. It should make No. 2 fire brick, or other refractory ware.

927. From 4½ miles northeast of Henderson, Rusk County. A hard, red, homogeneous, slightly micaceous shale used for making salt glazed pottery.

928. From 4 miles west of Tyler, Smith County. A buff burning pottery clay.

929. From 5 miles east of Henderson, Rusk County. A buff burning low grade fire clay. It is used for stoneware, but gives some trouble by cracking in drying and burning.

930. From a coal shaft at Bridgeport, Wise County. A hard dense shaley clay with low fusibility. It contains much organic matter which causes trouble if the clay is not burned very carefully. It might be used for face brick, or, on account of its easy fusibility, for slip clay.

932 and 933. From Rock Creek, 15 miles west of Weatherford, Parker County. Two samples of blue pottery clay. The first has been used for common unglazed pottery. The second might be used for the same purpose, though its fusion point is lower, or it might be used for hollow or vitrified brick. Both of these clays burn brown.

937. From Wilson plantation at Fulshear, Fort Bend County. A soft, porous, fast slaking clay stained with limonite. It is too sandy to make dry-press bricks, but makes good wet molded bricks, burning to a brown color.

943. From 5 miles northwest of Cisco, Eastland County. A blue shale, sample taken 40 feet below the surface of the ground and above a seam of coal. It should make good press brick of a red-buff color, but must be burned very slowly because of the organic matter present.

944. Same as sample No. 943. A blue shaley clay immediately below the coal seam as described above. This burns buff and should make good brick by either dry-press or stiff mud methods. It might also make good paving brick.

945. From 3½ miles east of Austin, Travis County. A buff calcareous shale, containing bunches of gypsum crystals. It is very dense and the wet plastic mass is very sticky. It must be molded by dry-pressing, unless mixed with sand or less plastic clay. It also tends to swell and blister when wet molded.

946. From East Waco, near the Brazos River, Waco, McLennan County. Sample taken from mixture of run-of-bank material. It burns to from light red to gray, and is made into common building brick.

947. From ¼ mile north of the source of Sample 946, McLennan County. A yellow river silt used in making soft mud common brick. It fuses very readily but its highly silicious character renders it unsuitable for slip glazing.

948. From 3 miles southwest of Lavernia, Wilson County. A homogeneous clay with occasional iron stains. It is used for slip glazed stoneware.

949. From south bank of Leon Creek, near San Antonio, Bexar County. A light yellow calcareous clay containing limestone pebbles. Care must be taken in mining to exclude these pebbles as far as possible. The clay burns yellow and fuses very easily. It has been used as a slip clay, for which purpose it gives good results.

950. From 2 miles southeast of Carmona, Polk County. The raw clay is light blue, but weathers to a white. It is of very low fusibility and its only use would be for a slip clay.

951. From 13 miles northeast of Navasota, Grimes County. A white porous clay. It has low fusibility due to high potash and soda content. It is worth trying as a slip clay.

952. From Bremond, Robertson County. A whitish-gray clay of high refractoriness. It was tested for china clay purposes, but found to be too sandy for this purpose as well as to burn to too dirty a white. It might, however, be used as a fire clay.

953. From 3½ miles south of Denny, Falls County. A hard, light brown, homogeneous clay. It burns buff to cone 9, when it turns gray, and at cone 12 it swells some and shows signs of blistering. It is used for stoneware.

954 and 955. From 2 miles north of Headsville, Limestone County. These are clays from adjacent strata, both being fair grade fire clays, gray when raw and burning to a near white. They both give porous bodies on burning, with low fire shrinkage. For pottery purposes they would have to be mixed with a denser burning clay, but they should make fair fire bricks without any such mixing. No. 955 would be even more refractory than it is except for its high sand content. Its refractoriness could probably be increased by washing out some of the sand.

956 and 957. From 5½ miles east of Elgin, Bastrop County. These are from two strata, that from which sample No. 957 was taken being a dark gray clay stratum lying on top of a layer of almost black clay from which No. 956 was taken. Both burn buff and are of fairly good refractoriness, No. 956 being somewhat more refractory than No. 957, the difference probably resulting from the greater amount of sand present in the latter. In spite of this refractory property, both burn to a hard dense body at a comparatively low temeperature.

958. From Elgin, Bastrop County. A light brown clay which burns buff. It is used to make a good grade of dry-press brick.

959. From clay pit at Elgin, Bastrop County. A yellowish surface clay which burns red. It is used to make a good grade of red pressed brick.

960. From 3 miles north of McDade, Bastrop County. This is a sample of a black sedimentary clay. It burns buff, which turns to gray at cone 14. It is used as a component of a clay mixture for making common stoneware.

TABLE III

CHEMICAL ANALYSES OF TEXAS CLAYS AND SHALES

Made by Mr. J. E. Stullken, of the Bureau of Industrial Chemistry

Laboratory Number	SiO_2	Al_2O_3 and Fe_2O_3	Na_2O and K_2O	CaO	MgO	SO_3	H_2O	CO_2	TiO_2
C 672	70	15							
C 875	16.44	9.32	1.99	39.69	0.0		4.60	25.30	
C 902	64.23	11.16 3.80	3.52	3.73	1.10		12.47		
C1009									
(1)	48.70	24.28	2.78	5.97			11.30	6.70	
(2)	20.20	10.50	1.50	35.07			5.70	26.66	
C1029	44.68	14.85 3.26	0.96	18.85	1.31		6.46	7.56	2.16
C1050	45.10	18.00		13.60			13.07	7.83	
C1054	67.30	14.58 5.73	1.47	1.97	1.46	4.52	3.06		
C1058	86.32	12.44							
C1109	68.25	21.05 2.53	3.24	1.21			3.65	0.0	
C1156	71.48	14.82 3.89	0.40	1.97	2.14		5.19		
C1180	32.12	9.49 18.83		11.52	0.37	4.56		7.08	*
C1185	38	36 8		11		some		8	
C1306	70.04	19.75		0.54			2.60		
C1334	66	26		1	some	some			
C1341									
(1)	68.27	18.00		0.67	0.22		8.70		
(2)	68.08	15.98		1.00	0.12		9.00		
(3)	69.25	15.43		0.67	0.38		9.18		
C1347	71.00	15.20	5.46	tr.			2.35		
C1351	23.85	10.22		29.16	0.0	2.60	5.80	21.48	
C1352	82.18	12.32	2.93				2.41		
C1366									
"A"	44.30	39.71 0.29		0.66	0.0		14.90		0.50
"B"	41.73	36.55 5.12		0.66	0.0		14.90		0.50
C1367	44.95	39.61 0.94	1.63	0.42			14.91		tr.
C1368	45.12	27.14 1.13	1.26	0.64			14.73		tr.
C1441	41.76	39.00 1.14	1.54	0.80	0.17		16.60		0.0
C1442	58.46	26.95 2.12	1.43	0.80	0.22		10.21		1.5
C1443	58.83	17.28 13.72	1.41	0.53	0.19		6.60		1.2
C1511	70.50	17.44 1.99	1.99	1.04			7.31		
C1586	78.83	4.58 9.99	1.04	1.25			4.07		
C1604	62.00	15.68 5.32	3.48	3.35		0.14	8.30		
C1814	75.45	10.86 2.49	2.82	2.19	0.0		7.54		
C1816	78.15	14.61	1.75	0.82			5.05		
C1845	59.70	27.62		2.20			6.58		
C1846	60.76	20.93					6.69		
C1847	58.52	28.35					7.60		
C1942	55.00	19.10 6.29	3.18	3.18	3.24		10.00		
C1944	73.80	15.93 3.47	2.29	0.57			3.50		
C1949	63.40	19.54 4.26	3.40	0.31			9.12		
C1966	48.20	13.45 6.10	4.85	7.90	4.92	0.27	14.55		
C2530	10	6.0		42.8		1.6	4.2	33.6	
C2802	15.37	4.44 2.21	2.74	39.66	0.79		3.86	31.13	

*1.28% P_2O_5

TABLE IV

RESULTS OF CERAMIC TESTS MADE BY THE BUREAU OF INDUSTRIAL CHEMISTRY

C1123 to C1136 inclusive, preliminary ceramic tests as follows:

Number		Cone	Fire shrinkage
C1123	A	010	— 1.4
	B	05	— 1.08
	C	1	— 0.42
C1124	A	010	+ 1.21
	B	05	+ 3.05
	C	1	+11.5
C1125	A	010	— 1.66
	B	05	— 1.38
	C	1	+ 0.83
C1126	A	010	+ 1.86
	B	05	+ 2.70
	C	1	+ 4.00
C1127	A	010	— 0.58
	B	05	+ 0.74
	C	1	+ 2.74
C1128	A	010	+ 2.45
	B	05	+ 3.42
	C	1	+ 8.18
C1129	A	010	+ 0.92
	B	05	+ 1.68
	C	1	+ 7.08
C1130	A	010	+ 1.25
	B	05	+ 1.77
	C	1	+ 4.05
C1131	A	010	+ 3.05
	B	05	+ 3.35
C1132	A	010	+ 2.70
	B	05	+ 5.01
	C	1	+ 8.72
C1133	A	010	+ 1.87
	B	05	+ 2.81
	C	1	+ 3.64
C1134	A	010	+ 1.31
	B	05	+ 4.40
	C	1	+20.8
C1135	A	010	+ 5.72
	B	05	+ 6.78
	C	1	+11.65
C1136	A	010	+ 1.50
	B	05	—27.9
	C	1	—56.7

C1158, burning trial on stiff mud bricklets:

Cone	010	08	04	02	1	3	5
Temperature	950°C	990	1070	1110	1150	1190	1230
Color	brick red	brick red	brown red	brown red	light brown	light brown	brown
Hardness	hard	hard	hard	hard	hard	hard	hard
Fire Shrinkage	—1.0	—1.9	—0.1	—0.5	—0.7	—0.7	—0.2

C1159, burning trial on stiff mud bricklets:

Cone	08	04	1	3	5
Temperature	990°C	1070	1150	1190	1230
Color	red	red	red-brown	brown	dark brown
Hardness		all test pieces cracked badly			
Fire shrinkage	—1.2	—1.8	—2.4	—1.2	—0.4

C1160, burning trial on stiff mud bricklets:

Cone	08	04	1	3	5
Temperature	990°C	1070	1150	1190	1230
Color	red	red	brown	brown	dark brown
Hardness	hard	hard	hard	steel hard	steel hard
Fire shrinkage	5.3	6.0	7.7	9.4	12.7

C1161, burning trial on stiff mud bricklets:

Cone	08	04	3	5
Temperature	990°C	1070	1190	1230
Condition	cracked	cracked	fused	fused
Fire shrinkage			8.5	14.2

C1347, burning trials on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light yellow	light yellow	light yellow	yellow brown	yellow brown	gray	gray	gray
Hardness	med.	med.	med.	med.	hard	very hard	very hard	very hard
Fire shrinkage	—1.5	+0.1	0	+0.4	1.9	10.7	11.0	12.3
Porosity	29.6	28.3	26.8	27.0	26.8	19.0	18.5	16.9

C1352, burning trials on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	flesh	flesh	flesh	flesh	flesh		light brown	light gray
Hardness	hard	med.	med.		hard	hard	steel hard	steel hard
Fire shrinkage	—0.8	—1.2	—1.5	—2.0	—0.2	—0.4	—0.3	—0.6
Porosity	26.3	26.4	26.7	26.5	26.4	24.0	24.3	24.2
			Fusion at Cone 33					

C1352, burning trials on dry press bricklets:

Cone	010	08	06	04	02	1
Temperature	950	990	1030	1070	1110	1150
Color	flesh	flesh	light buff	light buff	light buff	ash gray
Hardness	soft	med.	med.	hard	stone hard	steel hard

C1358, burning trials on bricklets made by semi-dry process:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light red	light red	light red	brick red	brick red	dark red	dark red	dark red
Hardness	very soft	very soft	very soft	very soft	med.	hard	very hard	very hard
Fire shrinkage	0.5	—1.0	—1.5	—1.0	—0.3	—3.3	—8.1	—7.5
Porosity	28.7	29.6	28.7	27.8	29.4	30.1	27.3	28.1

C1381, burning trial on stiff mud bricklets:

Cone	010	08	06	04	02
Temperature	950	990	1030	1070	1110
Color	light orange	light orange	light red	red	red
Hardness	hard	hard	steel hard	steel hard	steel hard
Fire shrinkage	—2.6	+0.3	4.3	7.1	9.4
Porosity	31.4	20.9	18.2	16.5	15.1

C1381, burning trial on dry press bricklets:

Cone	010	08	06	04	02
Temperature	950	990	1030	1070	1110
Color	orange	orange	light red	red	red
Hardness	hard	steel hard	steel hard	steel hard	steel hard
Fire shrinkage	—3.1	—3.1	+5.3	11.5	8.4
Porosity	27.1	22.8	19.5	9.0	12.0

C1382, burning trials on stiff mud bricklets:

Cone	010	08	06	04	02
Temperature	950	990	1030	1070	1110
Color	orange	orange	orange	red	red
Hardness	hard	steel hard	steel hard	steel hard	steel hard
Fire shrinkage	—1.1	+5.1	10.9	16.6	15.4
Porosity	23.9	19.5	13.6	1.5	

C1382, burning trial on dry press bricklets:

Cone	010	08	06	04	02
Temperature	950	990	1030	1070	1110
Color	light orange	orange	light red	light red	red
Hardness	med.	hard	steel hard	steel hard	steel hard
Fire shrinkage	—3.9	+1.6	8.6	18.1	21.0
Porosity	32.7	26.6	19.7	8.1	4.3

C1383, burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light red	light red	light red	red	red	red	red	brown red
Hardness	med.	med.	med.	hard	hard	hard	hard	hard
Fire shrinkage	—58.4	—57.5	—57.9	—57.6	—59.9	—57.7	—58.1	—58.0
Porosity	23.4	23.4	24.0	24.1	23.9	24.1	23.8	23.1

C1383, burning trial on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color				light red	red	red	red	light red
Hardness	Entirely too soft for all commercial purposes			med.	med.	med.	med.	med.
Fire shrinkage				—53.3	—52.7	—53.4	—52.8	—53.3

C1384, burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light red	light red	light red	red	red	red	red	brown red
Hardness	med.	med.	med.	med.	med.	med.	med.	med.
Fire shrinkage	—57.8	—58.1	—60.0	—56.9	—56.2	—56.2	—56.7	—57.2
Porosity	24.4	24.5	23.8	25.0				

C1384, burning trial on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color					light red	light red	light red	bright red
Hardness	Entirely too soft for all commercial purposes				med.	med.	med.	med.
Fire shrinkage					—52.6	—53.0	—50.0	—53.6

C1438, burning trial on stiff mud bricklets:

Cone	010	06	02	4	6	8	12	14
Temperature	950	1030	1110	1210	1250	1290	1370	1410
Color	light red	light red	light red	red	red	tan	choc-olate	choc-olate
Hardness	very hard	very hard	steel hard	steel hard	steel hard	steel hard	steel hard	steel hard
Fire shrinkage	+1.9	+4.0	+8.2	+8.6	+8.7	+12.3	+10.3	
Porosity	23.6	22.0	17.0	13.6	14.2	10.4	7.7	fused

C1438, burning trial on dry press bricklets:

Cone	010	06	02	4	6	8	12
Temperature	950	1030	1110	1210	1250	1290	1370
Color	light red	light red	light red	red	red	tan	choc-olate
Hardness	med.	very hard	very hard	steel hard	steel hard	steel hard	steel hard
Fire shrinkage	3.3	5.6	10.7	12.8	12.9	15.5	17.2
Porosity	35.6	33.4	29.5	31.2	30.2	28.5	29.4

C1439, burning trial on stiff mud brickletss

Cone	010	06	02	4	6	8	12	14
Temperature	950	1030	1110	1210	1250	1290	1370	1410
Color		reddish yellow	light red	light red	light red	light brown	light brown	light brown
Hardness		hard	very hard	steel hard	steel hard	steel hard	steel hard	steel hard
Fire shrinkage		0.9	2.8	3.8	3.6	5.6	5.8	5.9
Porosity		23.5	21.6	21.3	20.4	16.8	16.7	17.1
		Fused at Cone 29						

C1439, burning trial on dry press bricklets:

Cone	010	4	8	12	14
Temperature	1110	1210	1290	1370	1410
Color	light red	light red	grayish-brown	grayish-brown	grayish-brown
Hardness	med. hard	med. hard	steel hard	steel hard	steel hard
Fire shrinkage	1.6	1.2	3.8	4.0	5.4
Porosity	7.2	5.5	15.8	15.5	

C1440, burning trial on stiff mud bricklets:

Cone	010	06	02	4	6	8	12	14
Temperature	950	1030	1110	1210	1250	1290	1370	1410
Color	light yellow	light red	light red	light red	light red	light brown	light brown	light brown
Hardness	med.	hard	hard	hard	hard	very hard	steel hard	steel hard
Fire shrinkage	—0.2	—0.1	0	0	0	0	0	0
Porosity	30.6	30.3	30.0	30.0	29.1	28.6	28.4	28.4

Fused at Cone 29

C1440, burning trial on dry press bricklets:

Cone	010	06	02	4	6	8	12	14
Temperature	950	1030	1110	1210	1250	1290	1370	1410
Color	light yellow	bright red	bright red	bright red	gray	gray	gray	gray
Hardness	tender	tender	med.	med.	med.	hard	very hard	very hard
Fire shrinkage	1.3	1.9	1.5	2.0	2.0	1.0	1.2	1.8
Porosity	26.5	27.7	28.1	27.7	26.7	26.5	26.0	25.9

C1446, burning trial on dry press bricklets:

Cone	06	02	1	3	5	7	8+
Temperature	1030	1110	1150	1190	1230	1270	1300
Color	light yellow	yellow	very lt. red	very lt. red	gray	gray	gray
Hardness	med.	med.	med.	hard	steel hard	steel hard	steel hard
Fire shrinkage	7.1	10.4	14.8	14.5	20.1	20.3	20.6
Porosity	27.6	23.7	21.5	19.7	12.2	12.2	11.6

C1482, slate colored clay with lime pebbles.
Water of plasticity, 27.2%. Drying shrinkage, 25%.
Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3
Temperature	950	990	1030	1070	1110	1150	1190
Color	light pink	light pink	light pink	cream	cream	light yellow	light yellow
Hardness	very hard	very hard	very hard	very hard	very hard	very hard	very hard
Fire shrinkage	2.1	broken	—7.3	—9.6	—4.7	—6.7	
Porosity	39.7	due to lime	46.2	48.0	44.7	37.3	Fused at Cone 4

C1483, red clay with lime pebbles.
Water of plasticity, 32.4%. Drying shrinkage, 31.6%.
Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1
Temperature	950	990	1030	1070	1110	1150
Color	lt. red	lt. red	lt. red	lt. red	lt. red	lt. red
Hardness	very hard	very hard	very hard	very hard	very hard	very hard
Fire shrinkage	7.2	6.7	7.5	7.3	5.5	
Porosity	23.1	23.6	25.3	22.7	17.4	Fused

C1512, burning trial on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light red	light red	light red	light red	red	dark red	brown	brown
Hardness	med.	med.	hard	very hard	steel hard	steel hard	steel hard	steel hard
Fire shrinkage	4.8	5.8	9.6	15.8	17.7	20.8	21.6	21.8
Porosity	25.2	25.0	22.4	17.1	15.3	12.4	11.9	9.8

Small cracks begin to form at Cone 06 and get worse at higher temperatures. Viscous at about Cone 15.

C1520, burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color				Salmon to cream				
Hardness	med.	med.	med.	med.	med.	med.	med.	med.
Fire shrinkage	4.4	5.1	5.8	6.3	7.9	8.9	9.1	9.6
Porosity	44.8	44.2	44.0	43.7	43.3	42.3	42.0	40.7

C1520, burning trial on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	cream	cream	light cream	light cream	light cream	light cream	light cream	light cream
Hardness	soft	soft	soft	soft	soft	soft	med. hard	med. hard
Fire shrinkage	5.5	5.7	6.5	7.7	8.7	9.4	9.3	10.2
Porosity	40.8	41.0	41.1	40.0	39.5	39.3	38.7	38.0

C1521, stiff mud bricklets containing different proportions of grog burned to Cone 08:

Pct. of grog used	5%	10%	15%	25%	35%	50%
Color						light slate
Hardness	med.	med.	med.	soft	soft	tender
Fire shrinkage	0.4	1.7	0.8	1.1	0	1.8
Porosity	23.7	23.0	23.8	26.7	27.3	29.7

Best surface obtained with 15% mixture.

C1528, burning trial on dry press bricklets:

Cone	08	06	04	02	1	3	5	8
Temperature	990	1030	1070	1110	1150	1190	1230	1290
Color	light red	light red	light red	brick red	brick red	brick red	brick red	brown
Hardness	soft	soft	soft	med.	med.	med.	med.	med.
Fire shrinkage	1.5	1.4	2.1	2.8	2.9	2.8	2.5	3.3
Porosity	25.8	26.1	26.4	27.0	26.8	26.6	26.6	25.2

C1603, drying shrinkage 13%, burning trial on

	stiff mud bricklets			dry press bricklets:			
Cone	08	06	02	08	06	02	1
Temperature	990	1030	1110	990	1030	1110	1150
Color	salmon	light red	brick red	salmon	light red	brick red	
Hardness	very hard	steel hard	steel hard	very hard	steel hard	steel hard	Fused
Fire shrinkage	9.7	21.3	32.8	16.4	31.6	39.0	
Porosity	29.0	16.6	4.0	27.2	14.5		

C1605, plasticity—high; drying shrinkage—excessive; burning trial on dry press bricklets:

Cone	08	06	02	1
Temperature	990	1050	1110	1150
Color	lt. red	lt. red	bright red	dark red
Hardness	hard	hard	very hard	steel hard
Fire shrinkage	7.9	9.9	13.8	26.8
Porosity	24.0	24.0	22.6	6.7

C1676, burnng trial on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light	light	red	red	red	red	red	
Hardness	very soft	very soft	med. hard	very hard	very hard	badly cracked	fused	
Fire shrinkage	3.5	7.4	10.0	11.6	13.7			
Porosity	33.0	30.3	30.3	25.8	23.8			

C1676, plasticity—high; drying shrinkage—excessive; burning trial made on stiff mud bricklets made with raw clay plus 20% sand, such a mixture has 17.2% drying shrinkage.

Cone	010	08	06	04	02	1	3
Temperature	950	990	1030	1070	1110	1150	1190
Color	buff	buff	light red	light red	red	red	red
Hardness	med.	med.	med.	hard	hard	steel hard	steel hard
Fire shrinkage	4.4	4.1	7.7	11.9	14.9	16.7	18.0
Porosity	33.6	33.6	30.9	27.9	26.2	23.3	20.6

C1814, burning trial with dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff
Hardness	med.	med.	med.	med.	hard	very hard	steel hard	steel hard
Fire shrinkage	13.2	17.3	19.6	21.6	23.6	25.9	30.2	33.8
Porosity	37.9	32.7	29.2	28.2	26.5	24.6	21.5	17.1

C1814, burning trial on bricklets made of 40% raw clay and 60% grog:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff	lt.buff
Hardness	med.	med.	med.	med.	med.	med.	med.	hard
Fire shrinkage	1.4	3.1	4.8	9.1	10.0	12.1	14.8	16.1
Porosity	39.9	39.1	37.0	34.8	33.8	33.3	32.0	31.0

C2097, Red, siliceous clay. Plasticity—low; water of plasticity, 21.8%; drying shrinkage, 15.4%. Burning trial on stiff mud bricklets:

Cone	08	06	04	1
Temperature	990	1030	1070	1150
Color	red	red	red	dark red
Hardness	very soft	very soft	very soft	very soft
Fire shrinkage	—4.1	—4.0	—4.4	—3.5
Porosity	25.6	27.2	27.9	

C2098, Dark red clay. Plasticity—medium; water of plasticity, 23%; drying shrinkage, 22.4%. Burning trials on

	stiff mud bricklets:				dry press bricklets:			
Cone	08	06	04	1	08	06	04	1
Temperature	990	1030	1070	1150	990	1030	1070	1150
Color	red	red	red	red	red	red	red	dark red
Hardness	soft	soft	soft	soft	soft	soft	soft	hard
Fire shrinkage	—3.3	—3.6	—3.3	+2.1	—1.3	—0.9	—1.5	+2.9
Porosity	25.2	24.4	24.2		32.5	32.3	33.8	25.0

C2149, Plasticity—poor; water of plasticity, 15.3%; drying shrinkage, 9.5%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	buff	buff	buff	buff	buff	buff	buff	buff
Hardness	soft	soft	med.	med.	very hard	very hard	very hard	very hard
Fire shrinkage	—3.4	—3.5	—3.6	—3.5	—2.9	—2.4	—2.4	—1.7
Porosity	27.7	25.4	26.4	25.2	24.6	24.1	24.0	22.7

C2149, burning trial on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	buff	buff	buff	buff	buff	buff	buff	buff
Hardness	soft	soft	soft	soft	soft	med.	med.	very hard
Fire shrinkage	—2.1	—1.8	—2.0	—2.7	—2.1	—2.2	—1.9	—1.3
Porosity	27.8	28.1	28.0	28.8	28.7	28.6	28.1	27.2

C2162, plasticity—good; drying properties—good; water of plasticity, 28%; drying shrinkage, 25.8%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	salmon	salmon	salmon	lt. red	red	red	red	dk. red
Hardness	med.	hard	very hard	steel hard		vitrified		
Fire shrinkage	1.6	3.3	8.3	24.0	25.4	25.5	25.6	24.8
Porosity	31.8	31.0	26.7	7.0	0.6	0.4	0.1	0.2

C2162, burning trial on dry press bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	salmon	salmon	salmon	lt. red	red	red	red	choc.
Hardness	soft	med.	med.	steel hard	steel hard	steel hard	cracked	
Fire shrinkage	0.3	2.3	6.2	20.6	25.0	26.4		
Porosity	35.4	35.0	32.8	19.5	14.5	11.7		

C2570, raw color—almost white; plastic color—blue gray. Plasticity—medium; drying properties—good; water of plasticity, 20.5%; drying shrinkage, 16.85%. Burning trials on stiff mud bricklets:

Cone	06	02	1	3	11
Temperature	1030	1110	1150	1190	1350
Color	white	white	cream	cream	light cream
Hardness	very soft	very soft	soft	med. soft	med. hard
Fire shrinkage	—0.95	+0.07	+1.2	1.6	5.7
Porosity	14.7	13.5	12.8	12.6	9.9

C2570, raw clay mixed with 5% finely ground calcium carbonate. Plasticty of mixture—medium; drying properties—good; water of plasticity, 25.25%; drying shrinkage, 13.0%. Burning trial on stiff mud bricklets made from this mixture:

Cone	06	02	1	3	11
Temperature	1030	1110	1150	1190	1350
Color	white	white	cream	cream	speckled buff
Hardness	very soft	med. soft	med. soft	med. soft	hard
Fire shrinkage	—0.5	+0.3	0.8	1.1	3.0
Porosity	14.0	13.0	12.4	12.7	11.4

C2570, raw clay mixed with 5% finely ground feldspar. Plasticity of mixture—medium; drying properties—good; water of plasticity, 18.9%; drying shrinkage, 13.6%. Burning trial on stiff mud bricklets made from this mixture:

Cone	06	02	1	3	11
Temperature	1030	1110	1150	1190	1350
Color	white	very lt. cream	lt. cream	cream	grayish white
Hardness	very soft	soft	med. soft	med. hard	steel hard
Fire shrinkage	—0.5	+1.3	2.3	3.5	11.8
Porosity	14.5	13.3	12.4	11.9	7.1

C2635, plasticity—medium; drying properties—good; water of plasticity, 7.6%; drying shrinkage, 29.1%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1930	1070	1110	1150	1190	1230
Color	lt. red	light red	light red	very light red	very light red	very light red	very light red	
Hardness	med.	med.	hard	hard	steel hard	steel hard	vitrified	fused
Fire shrinkage	0.4	0.2	0.2	—0.7	6.8	14.0	—2.3	
Porosity	13.4	14.0	14.0	14.0	20.0	3.7	0.8	

C2994, light red clay with some lime and sandstone gravel. Plasticity—medium; drying properties—good; water of plasticity, 29.8%; drying shrinkage, 29.2%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	red	red	red	dark red				
Hardness	hard	hard	steel hard			fused		
Fire shrinkage	24.2	18.0	14.2	13.1				
Porosity	41.2	38.0	32.7	28.9		vitrification range Cone 04–02		

C2995, light yellow clay with gray streaks, some sandstone gravel. Medium hard. Medium slow slaking. Plasticity—fair; drying properties—moderate. Water of plasticity, 24.9%; drying shrinkage, 23.9%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light red	light red	light red	light red	dark red	dark red	dark red	choc.
Hardness	med.	hard	steel hard			vitrified		
Fire shrinkage	—1.2	+1.5	7.5	16.3	20.7	18.5	14.4	—3.4
Porosity	28.1	25.1	20.7	9.8	1.5	1.3	1.7	15.0

C2996, light yellow clay with gray streaks, no objectionable matter visible. Medium hard. Slow slakng. Plasticity—medium; drying properties—fair. Water of plasticity, 24.7%; drying shrinkage, 20.9%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light red	light red	light red	light red	red	red	red	dark red
Fire shrinkage	0.3	4.8	9. 4	20.9	18.2	8.9	4.0	—9.5
Porosity	28.0	24.4	18.8	5.1 vitrified	0.8	2.9	6.7	18.9

C2997, clay contains small amount of iron stained sandstone gravel. Plasticity —fair; drying properties—medium. Water of plasticity, 33%; drying shrinkage, 33.4%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	bright red	bright red	bright red	bright red	bright red	red	red	dk. red
Hardness	med.	very hard	steel hard	steel hard		vitrified		
Fire shrinkage	2.9	7.1	11.7	21.4	20.3	12.1	4.8	—4.2
Porosity	27.4	24.1	19.7	4.9	0.8	4.3	11.1	13.5

C2998, clay contains small amount of iron stained sandstone gravel. Plasticity—fair; drying properties—medium. Water of plasticity, 30.7%; drying shrinkage, 27.3%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	br. red	bright red	bright red	br. red	red	red	red	dark red
Hardness	hard	hard	very hard	steel hard	vitrified			
Fire shrinkage	4.0	5.5	10.4	23.5	24.4	14.7	10.0	—4.4
Porosity	27.4	27.1	22.6	4.7	0.4	3.7	6.9	21.3

C2999, clay contains a few lime pebbles. Plasticity—fair; drying properties—medium. Water of plasticity, 26.0%; drying shrinkage, 26.10%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	3	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	lt. red	light red	light red	red	red	red	red	red
Hardness	med.	hard	steel hard			vitrified		fused
Fire shrinkage	1.2	5.2	10.3	17.7	7.1	—10.6	—12.9	
Porosity	24.8	21.5	15.8	2.6	0.8	7.1	10.1	

C3000, dark gray clay with considerable amount of sandstone gravel. Medium hard. Slaking properties—slow; plasticity—medium low; drying properties—medium. Water of plasticity, 23.9%; drying shrinkage, 19.0%. Burning trial on stiff mud bricklets:

Cone	010	08	06	04	02	1	1	5
Temperature	950	990	1030	1070	1110	1150	1190	1230
Color	light red	lt. red	lt. red	red	dark red	dark red	dark red	choc.
Hardness	med.	hard	very hard	steel hard		vitrified		

NOTE.—All values for shrinkage stated in the above tables are stated on the basis of percent of ***Dry Volume.***

DISCUSSION OF SAMPLES OF TEXAS CLAYS AND SHALES ANALYZED AND TESTED BY THE BUREAU OF INDUSTRIAL CHEMISTRY

C 672. Source, 7 miles from Somerville, Burleson County. A light colored clay. No fire tests were made on this sample and the chemical analysis was not complete, but the analytical results obtained and the appearance of the clay, indicate that it may be of the fire clay type. June 13, 1918.

C 875. Source, near McKinney, Collins County. A complete chemical analysis was made on this sample. Results of this analysis show that the sample is entirely too calcareous even for common bricks. It might have possibilities as a cement material. November 3, 1919.

C 902. Source, not given, sent in from San Antonio. This sample was to be tested for kaolin, but the analysis shows it to contain too much iron, alkalies, and alkiline earths to be classed as a kaolin. It might be a good brick or pottery clay. No burning trials were made. June 19, 1919.

C1009. Source, Hemphill County. Two samples from this source were examined. No. 1 is brown in color and the analysis indicates that it may be a good brick clay. No. 2 is white and contains too much lime for brick. September 13, 1919.

C1029. Source, clay pit of an abandoned brick yard one mile north of San Benito, Cameron County. Chemical analysis of this sample showed it to be somewhat high in lime. Burning trials showed it to crack badly on burning and therefore to be no good for bricks or other ceramic ware. April 17, 1920.

C1050. Source, near Navasota, Grimes County. Chemical analysis indicates that this clay may be good for brick or tile. Its lime content is too high for any ceramic purpose. No burning trials were made. November 10, 1919.

C1054. Source, near Lufkin, Angelina County. Chemical analysis indicates that this clay may be good for bricks. No burning trials were made. December 30, 1919.

C1058. Source, near Taylor, Williamson County. Chemical analysis of this clay was not completed, but its gritty texture and the high silica content showed it to be largely sand, and of no value as a clay. December 20, 1919.

C1109. Source, near Eastland, Eastland County. Chemical analysis indicates that this may be a fairly good brick or pottery clay. No ceramic tests made. March 29, 1920.

C1123. Source, 3 miles southwest of Jacksonville, Cherokee County. No chemical analysis. Preliminary ceramic tests indicate possibility of suitability for high grade products. April 2, 1920.

C1124, C1125. Source, 1 mile southeast of Rusk, Cherokee County. No chemical analysis. Preliminary ceramic tests show possibility of suitability for high grade brick, stoneware or terra cotta. April 2, 1920.

C1126, C1127. Source, 2 miles southeast of Rusk, Cherokee County. No chemical analysis. Preliminary ceramic tests show possibility of suitability for high grade brick, stoneware or terra cotta. April 2, 1920.

C1128. Source, 6 miles southeast of Rusk, Cherokee County. No chemical analysis. Preliminary ceramic tests show that the clay burns to a hard body at low temperatures and might be suitable for good common brick. April 2, 1920.

C1129. Source, Redlawn, Cherokee County. No chemical analysis. Preliminary ceramic tests show that the clay may be made into a good common brick. April 2, 1920.

C1130, C1131. Source, 1 mile north of Marshall, Harrison County. No chemical analysis. Preliminary ceramic tests show that the clay may be made into good common brick. April 2, 1920.

C1132, C1133, and C1134. Source, 5 miles north of Pittsburg, Camp County. No chemical analysis. Preliminary ceramic tests indicate the possibility of a good building brick being made from a mixture of these three clays. April 2, 1920.

C1135. Source, 1 mile west of Pittsburg, Camp County. No chemical analysis. Preliminary ceramic tests show that only a poor grade of brick can be made from this clay. April 2, 1920.

C1136. Source, stratum lying under that represented by sample C1135. No chemical analysis. Preliminary ceramic tests show that this clay is unsuitable for any ceramic purpose. April 2, 1920.

C1156. Source, Texas Company-Arnold No. 13 well, depth 2975 feet, near West Columbia, Brazoria County. Complete chemical analysis. This clay was called Bentonite, but there is no record of any tests to determine the properties which would mark it as a Bentonite. The chemical analysis neither proves nor disproves anything in this respect. Because of the depth of the deposit, this clay is only of scientific interest. May 19, 1920.

C1158. Source, 1 mile north of Willis, Montgomery County. No chemical analysis. This sample was a red sandy clay which burned to a brick red, turning to brown at Cone 1. It contained hard pebbles, which would necessitate the clay being thoroughly ground and carefully screened before being made into ceramic ware. It would make a fair grade sandy building brick. May 29, 1920.

C1159. Source, near Santa Anna, Coleman County. This clay contained limestone pebbles and would not make a satisfactory brick due to cracking on firing. May 28, 1920.

C1160. Source, near Santa Anna, Coleman County. This was a very sandy clay which burned first to red and then to brown at Cone 1, becoming a deeper brown at higher temperatures. It would make a good sandy building brick, best burned at Cone 010. May 28, 1920.

C1161. Source, near Santa Anna, Coleman County. This contained more sand than clay, and also contained lime. It was shown to be unfit for ceramic uses. The test bricklets cracked badly, and the lime caused them to fuse rapidly below Cone 3. May 28, 1920.

C1180. Source, property of G. A. Parkinson, Bellview Park, South Austin, Travis County. Chemical analysis shows this to be a calcareous clay containing some sulphate and phosphate. The soluble salts would probably cause the formation of scum on burning and lessen the value of the clay for ceramic purposes. No ceramic tests were made. October 2, 1920.

C1185. Source, Alpine, Brewster County. Chemical analysis shows this to to be a slightly calcareous, high alumina clay. It would be impossible to predict its burning behavior without a trial, and none was made on this sample. August 21, 1920.

C1265, C1266, and C1267. Source, Burton, Washington County. No chemical analysis made. Preliminary ceramic tests on all three samples showed none of them to be fit for ceramic purposes. They have very tender properties both in the drying and firing stages. August 14, 1920.

C1306. Source, near Paris, Lamar County. This sample was a gray, slightly sandy clay. A chemical analysis was made, but no ceramic tests. September 4, 1920.

C1334. Source, near Moore Station, Frio County. Chemical analysis indicated that this might prove to be a good brick or pottery clay, but no ceramic tests were made. December 6, 1920.

C1341. Source, 12 miles east of Navasota, Grimes County. Three samples of this clay showed almost exactly the same chemical composition. This appears from the analysis to be a fairly good clay, but no ceramic tests were made. October 26, 1920.

C1347. Source, near Weldon, Houston County. Complete chemical analysis and ceramic tests made on this clay. This was such a sandy clay that it did not have sufficient plasticity to be worked by the stiff mud method. Dry press bricklets were formed and burned. They burned to a hard, gray body by Cone 02, turning gray slightly above this point. It would make a good dry press face brick if burned to Cone 02. November 8, 1920.

C1351. Source, 1 mile south of Austin, Travis County. This shale was shown by chemical analysis to be highly calcareous. It might prove good as a calcareous brick clay, but no ceramic tests were made. November 13, 1920.

C1352. Source, near Arlington, Tarrant County. Chemical analysis and complete ceramic tests were made on this clay, bricklets being molded by both stiff mud and dry press methods and burned, both kinds showing good behavior on burning. This clay burns first brown, then, at higher temperatures, to gray. The dry press bricklets are not very hard, and it would probably be best to use the stiff mud process, by which method a good building brick could be made. The clay was shown to have a fusion point at Cone 33, and hence should make a very good fire brick. November 19, 1920.

C1358. Source, near Crockett, Houston County. No chemical analysis made. This clay was of such low plasticity that stiff mud bricklets could not be formed, nor were dry press bricklets successfully molded, but when the clay was slightly moistened it was found that it would hold together when pressed. A series of bricklets were made by this semi-dry press method and burned with good results. They burn to a hard, dark red body at Cone 1, becoming harder at higher temperatures. The clay would make good hard common brick when molded by the semi-dry press method and burned between Cones 3 and 5. December 3, 1920.

C1366. Source, near Leakey, Real County. This included two samples of the Leakey kaolin discussed at length in Chapter V. Sample "A" is of a flesh color and analysis shows it to be of such purity as to be

probably a true kaolin. Sample "B" is of a blue color and is found to contain too much iron to be classed as a kaolin. It is probably from one of those portions of the deposit which have been contaminated by adjoining strata. December 15, 1920.

C1367. Source, near Leakey, Real County. This is another sample of the Leakey kaolin, described as being white and compact. The analysis shows it to be very pure. December 18, 1920.

C1368. Source, near Leakey, Real County. Still another sample of the Leakey kaolin, described as dull white in color. December 18, 1920.

C1380. Source, 3½ miles southwest of Carlos, Grimes County. No chemical analysis made. Preliminary ceramic tests show that the clay has such a high fire shrinkage that the test pieces cracked badly, and the material is unfit for ceramic purposes. December 30, 1920.

C1381. Source, 3 miles south of Santa Anna, Coleman County. No chemical analysis made. Burning trials made with both stiff mud and dry press bricklets. This burns to a good red color, becoming steel hard at Cone 06. It should make a good grade of common brick by either stiff mud or dry press methods. December 30, 1920.

C1382. Source, same as C1381. Another sample from the same deposit, showing substantially the same behavior on burning. December 30, 1920.

C1383 and C1384. Source, land of J. W. Hassell in Brazos County. Two samples from the same deposit, which were not analyzed chemically but were made into bricklets by both the stiff mud and dry press processes and burned. They both show a negative shrinkage—*i. e.* expansion—on burning and little decrease in porosity, indicating a high proportion of sand. Both burn a light red color up to Cone 5, at which all bricklets except the dry press bricklets of C1383 turn to a bright red. The dry press bricklets do not attain sufficient hardness for commercial purposes until the temperature of Cone 04 is reached, but will make a fair grade of common red brick if burned to above Cone 02. The stiff mud bricklets are medium hard throughout the burning range, those of C1383 becoming appreciably harder at Cone 04. None of the bricklets show cracking or undue warpage. January 7, 1921.

C1438. Source, 2¼ miles north of Arlington, Tarrant County. No chemical analysis. Ceramic tests by both stiff mud and dry press methods show the clay will make good common brick by either method, but best by the stiff mud. It burns to red at Cone 4, turning tan at Cone 8 and chocolate above that point. It fuses at Cone 14. February 23, 1921.

C1439 and C1440. Source, same as C1438. Two samples from the same deposit. They burn to a light red which turns to a light brown at Cone 8 when molded stiff mud. When dry pressed the light red turns to a gray-brown at Cone 6 to 8. Both samples fuse at Cone 29, and thus would make No. 2 fire brick. March 23, 1921.

C1441, C1442, and C1443. Source, near Leakey, Real County. Three more samples from the Leakey deposits, described respectively as white, dull stone, and blue stone color. The last named (C1443) contains a great deal of iron, in which respect, as well as in color, it seems to resemble C1366 "B", and likewise cannot be classed as a kaolin.

The other two compare favorably with other samples of true kaolin from that vicinity. March 23, 1921.

C1446. Source, near Crockett, Houston County. No chemical analysis made. Ceramic tests made on dry press bricklets. These burn to a gray color and crack badly on firing, but with care might make common brick. March 23, 1921.

C1482. Source, land of Miss Clara C. Barton, southeastern part of Val Verde County. No chemical analysis made. This is a slate colored clay containing lime lumps which would have to be very thoroughly ground if the clay were to be used for ceramic ware. The ground sample was made up into bricklets with 27.2% water, and showed a very high drying shrinkage (25% by volume). These bricklets, when burned, showed some tendency to warp and swell, but the clay would make fair common brick if burned at low temperatures. It fuses at Cone 4. May 7, 1921.

C1483. Source, same as C1482. No chemical analysis. This is a red clay, also containing lime pebbles, burning to a light red color and a very hard body at low temperatures. It fuses at Cone 1. Dry press bricklets cracked badly, so that neither this clay nor that represented by sample C1482 can be molded dry. The two might be used mixed together for making common brick by the stiff mud process. They would have to be thoroughly ground and pugged and burned to Cone 010. May 7, 1921.

C1511. Source, near Leakey, Real County. This kaolin sample shows about the same composition as others already discussed. July 9, 1921.

C1512. Source, from clay pit at Nodena, Titus County. No chemical analysis. Stiff mud bricklets cracked badly on drying and could not be burned. Dry press bricklets were burned, but those obtained at higher temperatures showed tendency to form many small cracks. The bricklets burned to a brown color, becoming steel hard at Cone 02 and viscous at about Cone 15. In order to find a way of overcoming the difficulties resulting from the cracking in drying and burning, a number of burning trials were made with various proportions of grog and sand with the raw clay, and the results of these trials indicated the possibility of making good building brick by the use of either grog or sand.

C1520. Source, near Browndel, Sabine County. No chemical analysis. Burning trials made on both stiff mud and dry press bricklets. The clay will make excellent building brick by either process. It burns to a cream color, and a fairly high temperature is required to produce a good hard body. July 28, 1921.

C1521. Source, from Taft, San Patricio County. This clay was tried out with various portions of grog in order to find what proportions could be used to produce a good brick. The grog used was composed of ground portions of the previously burned clay, and the raw clay-grog mixtures were burned to Cone 08. Best results were obtained with a mixture of 15% grog and 85% raw clay. August 13, 1921.

C1528. Source, land of R. F. Davies, northern part of Hunt County. No chemical analysis. This clay was very plastic, but showed such a high drying shrinkage that the mud bricklets could not be dried successfully. Dry press bricklets burned to a moderately hard body and a brown color. A good red common brick could be made from this clay burned to Cone 02. September 1, 1921.

C1586. Source not given, sent in from Waco, McLennan County. This sample is described as a shale. The chemical analysis indicates that it is rather high in free silica, and the clayey part is highly ferruginous. It is doubtful that it would prove of much value for ceramic purposes. No ceramic tests made. October 26, 1921.

C1603. Source, 2 miles north of Millican, in Brazos County. No chemical analysis. Burning trials made with both stiff mud and dry press bricklets. It has good plasticity and moderate drying shrinkage, and can be worked by either method. It burns to a brick red and fuses at Cone 1. It will make good brick, but has too much iron color for ware of any higher grade. November 22, 1921.

C1604. Source, 4 miles north of Riverside, in Walker County. Chemical analysis and burning trials were made on this sample. The clay is very plastic and dries to a dense hard body with an excessive drying shrinkage (40% by volume), so that all the stiff mud bricklets cracked badly in drying and only the dry press bricklets were burned. These burn to a reddish-yellow color and crack badly. Incipient fusion begins at Cone 4. The records of this trial have been lost but the files show the above mentioned results, and the conclusion that the clay cannot be used in the raw state, but that the difficulties above mentioned might be overcome by mixing an inert, non-plastic grog or sand with the clay. December 23, 1921.

C1605. Source, on S. A. U. & G. Ry. 8 miles south of San Antonio, Bexar County. No chemical analysis. The clay is very plastic, but shows such an excessive drying shrinkage that the wet mud bricklets crack badly and only the dry pressed bricklets were burned. These burn to a bright red, very hard body, at Cone 02, becoming dark red and steel hard at Cone 1. The firing shrinkage is somewhat high, and grog admixture would be necessary to reduce this if the clay were manufactured into bricks. Such an admixture might also lower the drying shrinkage so as to permit the making of stiff mud bricks. November 26, 1921.

C1676. Source, 11 miles north of Brenham, Washington County. No chemical analysis. This is a highly plastic clay with high drying shrinkage. The stiff mud bricklets that were burned contained 20% sand to reduce this shrinkage. This mixture had a drying shrinkage of 17.2% and burned to a good red color, becoming steel hard at Cone 1. It will make good common brick in this manner. The dry press bricklets made of the raw clay cracked badly at Cone 1 and fused at Cone 3. January 18, 1922.

C1814. Source, Franklin Ranch, northern part of McMullen County. This sample was sent in as a kaolin, but the high percentage of fluxes shown by the chemical analysis and the fact that it burns buff show that it cannot be classed as such. It has extremely high plasticity and high drying shrinkage. The plasticity was so high that as much as 75% of non plastic material could be added and the mixture still be worked. The clay burns to a hard buff body, and will make good face brick by either the stiff mud or the dry press process. For the stiff mud process inert grog or sand must be added to reduce the drying shrinkage. October 26, 1922.

C1816. Source, McMullen County. This was another sample tested for kaolin, evidently from a source the same as, or near to, sample C1814. Iron was not determined, but the lime and alkali contents is somewhat lower than in the former sample, and in this respect

it appears a little more favorable from the standpoint of kaolin. No ceramic tests were made, hence there is not enough evidence to class the sample as a kaolin. November 7, 1922.

C1845, C1846, and C1847. Source, in and near Marble Falls, Burnet County. All three of these clays seem to be fairly free from harmful impurities, but the analyses were not complete and no ceramic tests were made. November 7, 1922.

C1942. Source, clay pit of brick and tile plant in Potter County. This is a sample of the "Tecovas" shale. It is found by analysis to be high in lime, magnesia and the alkalies, and would not be suitable for use in other than heavy clay products. No ceramic tests were made. May 12, 1923.

C1944. Source, Colorado County. Chemical analysis indicates that this is a very sandy clay. There is not enough information on record to form the basis for any definite conclusion as to its value. May 22, 1923.

C1949. Source, Colorado County. This sample is described as a white clay. From the analysis it appears to be a fairly pure clay, but contains enough iron to make it very doubtful that the clay would burn white. No burning trials were made. May 22, 1923.

C1966. Source, Potter County. This is another sample of the "Tecovas" shale. The analysis shows it to be higher in lime, magnesia and the alkalies than the other sample, C1942. This does not look like a very promising material for ceramic purposes. June 15, 1923.

C1980. Source, same as C1942. This is another sample of the "Tecovas" shale which was given a series of ceramic tests, but no chemical analysis. Records of these tests were so badly charred by fire that only part of the results can be recovered for reproduction here. The clay required 23.7% water to give it plastic consistency, and showed a drying shrinkage of 15%, cracking rather badly in drying. It was concluded that this cracking could be overcome by the use of a non-plastic grog or sand mixed with the raw clay, and with such a mixture it was found that the test pieces burned to a good red color and hard body. The dry press bricklets cracked on firing. October 5, 1923.

C2097. Source, ½ mile from Dilley, Frio County. A red siliceous clay of low plasticity. It was made into bricklets with 21.8% water and showed a shrinkage of 15.4% on drying. The bricklets burned to a dark red at Cone 1, but never attained much strength. They showed the characteristic burning expansion of siliceous clays. No chemical analysis was made. February 1, 1924.

C2098. Source, same as C2097. A dark red clay of medium plasticity. It was made up into both stiff mud and dry pressed bricklets and burned. The stiff mud bricklets required 23% plastic water, and shrank 22.4% on drying. From the results of the ceramic tests it was concluded that the clay was unsuitable for ceramic purposes. No chemical analysis was made. February 1, 1924.

C2149. Source, 2 miles from Woodville, Tyler County. No chemical analysis. Ceramic tests were made on both stiff mud and dry press bricklets. The dry press bricklets are very tender, but if the clay were moistened it might be molded more successfully and made into common brick by a semi-dry process. The plasticity of the clay was very low. It was made into stiff mud bricklets with 15.3% water

and shrank 9.5% on drying. The clay burns to a buff and would make good common brick. The plasticity is too low for stiff mud bricks, but soft mud bricks might be made. April 24, 1924.

C2162. Source, land of Joe Vanham, ½ mile from Uvalde, Uvalde County. No chemical analysis. Ceramic tests were made on both stiff mud and dry press bricklets. The dry press bricklets became steel hard at Cone 04, but the structure was only of moderate strength. At Cone 3 the bricklets cracked badly. The stiff mud process worked much better. The clay was made up with 28% water, showing good plasticity and good drying behavior in spite of the high drying shrinkage (25.8%). The clay burns to a dark red, becoming steel hard at Cone 04 and vitrifying at Cone 02. It would make a light red common brick if burned up to Cone 04, or a dark red vitrified brick if burned to Cone 02 or higher. May 15, 1924.

C2530. Source, 2½ miles east of Ballinger, Runnels County. This clay is shown by analysis to be more lime than clay. It might be used as one of the components in the manufacture of Portland cement. July 1, 1925.

C2570. Source, near Thedford, Smith County. No chemical analysis. This is an almost white clay which burns cream. It was made up with 20.5% water, showing medium plasticity, and showed 16.85% drying shrinkage, with good drying behavior. It does not burn to a hard body until comparatively high temperatures are reached, but will make good hard face brick if burned to Cone 11. In an attempt to produce a mixture which would mature at a lower temperature, separate mixtures of this clay with 5% lime and 5% feldspar were made up and burned. The feldspar mixture worked best, producing a moderately hard body at Cone 3. August 5, 1925.

C2635. Source, land of A. M. Bruni, Webb County. No chemical analysis. The clay was made up into stiff mud bricklets, showing medium plasticity and good drying behavior in spite of the drying shrinkage of 29.1%. It burns to a light red and will make a good grade of common brick of medium hardness burned at Cone 010. A semi-dry process may be used. April 10, 1926.

C2802. Source, near Whitney, Hill County. This sample was described as shale, but shown by analysis to be largely limestone. Its use would be confined to cement making, and would be of use for this purpose only if a suitable clay were found close by to mix with it. December 23, 1927.

C2994 to C3000, inclusive. These samples were examined in connection with a survey of the clay resources of McCullough County made by Mr. Potter and reported in full on October 11, 1929. The locations of the several samples are as follows:

C2994. 1 mile east of Brady.

C2995. 5 miles south of Rochelle.

C2996. 5 miles south of Rochelle. This is a sample representative of a 28-foot thick deposit, sample C2995 representing the upper 3 feet of the same deposit.

C2997. 3½ miles east of Placid.

C2998. 3½ miles east of Placid, from a point in the bank of a ravine 100 yards above the location of sample C2997.

C2999. From ½ mile north of the location of sample C2997 and what appeared to be another outcrop of the same clay.

C3000. 200 yards south of the Ivy home, east of Placid.

All of the above samples would make common brick. C2994, C2995, C2997, C2998 and C3000 contain sandstone gravel, and C2994 and C2999 contain lime pebbles. All samples burn to a dark red, some becoming chocolate at higher temperatures. There is some possibility of making vitrified ware from some of the clays, but most of them have too short a vitrification range to be successfully made into this class of ware.

A number of records of partial or preliminary ceramic tests were found among the bureau files which do not bear laboratory numbers. These are reproduced below and designated by letters of the alphabet in order to distinguish them from the numbered tests preceding.

a. This is a report of an investigation to determine the cause of, and find a remedy for scumming trouble which was met by a brick plant at Stamford, Jones County. The amount of soluble salts in the clay was found to be low, so that it was concluded that scumming could not result from this cause. The oil which was used to lubricate the die was also investigated, but it was found that this did not cause the trouble. Finally the tempering water was examined and found to contain a considerable amount of Ca, SO_4 and Cl ions, and it was concluded that the scum resulted from these salts. It was suggested that barium carbonate in small amounts be added to the clay before tempering in order to precipitate the calcium and thus reduce the amount of soluble salts in the green brick.

b. A sample of clay from the land of W. A. Bell, in the east part of Walker County was given a partial ceramic test. The stiff mud bricklets were found to crack too badly in drying to be burned and only the dry press bricklets were burned. They burned to a red, steel hard body, becoming chocolate at Cone 04. The clay will make a fair grade of common brick by the dry press process if burned to about Cone 010.

c. Sample of clay from 2 miles from Crosbyton, Crosby County. Dry press bricklets would not stand up at all, and stiff mud bricklets had very tender drying qualities, also cracking badly on burning. An attempt was made to overcome these difficulties by mixing the raw clay with 10% grog, but bricklets made from this mixture cracked badly on burning, and bloated above Cone 05, where vitrification began.

d. Sample of clay from the Dean farm, western edge of Montgomery County. This was a bright yellow clay, of coarse gritty texture, fair plasticity and fair drying qualities. It contained lime pebbles which caused it to bloat and distort on burning, so as to be useless for ceramic purposes.

e. Four samples from the land of E. W. Cole, 6 miles east of Austin, Travis County. Preliminary tests showed the following results:

Sample Number	Plasticity	Raw Color	Wet Color	Objectionable Material	Texture	Drying Properties	Burned Color
1	fair	yellow	brown	gypsum	fine	very good	salmon
2	fair	lt. brown	lt. brown	gypsum	fine	fair	lt. red
3	fair	yellow	ocher	gypsum	fine	very good	dk. pink
4	medium	red	red	none	sandy	fair	red

f. Unfavorable ceramic tests on clay from 1 mile north of San Benito, Cameron County. The test pieces cracked badly at all temperatures.

g. A sample of brownish-gray clay from near Palestine, Anderson County. It had a good texture but contained a good deal of carbonaceous matter, fair plasticity and good drying qualities. It burned to a light red with very good burning behavior.

h. Eight samples of clay from Walker County, described as:

No. 1. Red burning siliceous clay with some tendency to warp.

No. 2. Red burning clay with moderate plasticity and high shrinkage.

No. 3. Yellow burning clay with low plasticity and low shrinkage.

No. 4. Good red color on burning. Moderate plasticity and high shrinkage. Gravel causes an unsound product.

No. 5. Red burning clay of moderate plasticity and high shrinkage. Cracks badly on drying and burning.

No. 6. This is a sand, too impure for glass and too fine for mortar.

No. 7. A clay of low plasticity and low shrinkage which burns to a fair red color and sound body.

No. 8. A clay of moderate plasticity and high shrinkage which burns to a good red color and sound body.

i. Two samples taken 1 mile west of Portland, San Patricio County. Both have high plasticity and high shrinkage, cracking badly on drying. They will not cohere at all when dry pressed. Neither are very promising as ceramic materials, but one might make a fair grade of finishing brick or tile and the other good common brick by the stiff mud process if grog or sand is added to overcome the high shrinkage and consequent cracking.

j. Sample of clay from near the southeast corner of Live Oak County. This clay had an extremely high drying shrinkage (48%) and cracked badly. It was mixed with 10% sand, which reduced the shrinkage somewhat and eliminated the cracking, so that bricklets of this mixture could be burned. They burn hard at Cone 010 and fuse at Cone 6. This clay is not promising as a ceramic material.

k. A sample taken on the road between Belton and Killean, Bell County, and supposed to be kaolin. It was found to be 60% calcium carbonate (limestone).

l. This was a sample of fire brick from Sulphur Springs, Hopkins County, which was given a fusion test and a chemical analysis. It was found to fuse at Cone 28, and to have the following chemical composition:

Silica	71.73%
Alumina	22.20
Iron oxide	1.25
Lime	1.18
Alkali oxides	2.54
Loss on ignition	1.06
Total	99.96

The following samples were taken along the lines of the San Antonio and Aransas Pass Railway (now a part of the Southern Pacific System) and preliminary ceramic tests were made on them by Mr. Potter as a part of an investigation of the natural resources of the territory served by that railroad. Officials of the Southern Pacific lines have kindly given permission for the printing of this information in this bulletin. The sources of these samples are indicated by the initials preceding the sample numbers, and are as follows:

A-1 and A-2—Adkins, Bexar County.

AP-1 and AP-2—Aransas Pass, San Patricio County. These two samples of calcareous clay were also analyzed chemically to determine their fitness for use as raw materials for cement. The analyses were:

	AP-1	AP-2
SiO_2	44.91%	50.60%
Fe_2O_3 and Al_2O_3	6.50	12.75
CaO	17.37	13.66

Neither of these is suitable for cement manufacture. AP-1 is entirely too low in alumina. AP-2 has about the correct alumina ratio, but the silica is rather high, and if lime were added the alumina ratio would decrease and would then be too low.

Ca-1 to Ca-5, inclusive—Calaveras, Wilson County.

CC-1 to CC-7, inclusive—Corpus Christi, Nueces County. Numbers 1, 2, and 3 are from Weil Brothers, 4, 5, and 6 from H. M. Baker, and 7 from Robert Toenisch.

Fl-2 to Fl-11, inclusive—Flatonia, Fayette County.

FC-1 to FC-3, inclusive—Falls City, Karnes County.

Gd-1—Giddings, Lee County.

Go-1 to Go-5, inclusive—Gonzales, Gonzales County.

H-1 and H-2—From Sparks Coal Company mine at Hicks, Lee County.

Kc-1 to Kc-5, inclusive—Karnes City, Karnes County.

Lu-1 to Lu-4, inclusive—Luling, Caldwell County (from old brick yard).

Ma-1 to Ma-3, inclusive—From C. B. McAnally, Mathis, San Patricio County.

Mu-1 to Mu-8, inclusive—From J. C. Melcher, Muldoon, Fayette County.

N-1 to N-3, inclusive—From J. B. Noak, Winchester, Fayette County.

Pl-1 to Pl-8, inclusive—From Portland, San Patricio County.

R-1 to R-6, inclusive—From Rockdale, Milam County.

RP-1 to RP-6, inclusive—From Rockport, Aransas County. Sample RP-4 was found to fuse at Cone 5, and sample RP-3 to begin to fuse at Cone 5 but not be completely down until Cone 8.

Wi-1 to Wi-3, inclusive—From Walter Petet, Winchester, Fayette County.

Yo-1 to Yo-3, inclusive—From Yoakum, Lavaca County.

TABLE V

PRELIMINARY CERAMIC TESTS MADE FOR THE S. A. & A. P. RY.

Sample Number	Plasticity	Behavior of dry press bricklets	Drying behavior of stiff mud bricklets	Linear Shrinkage %	Burning behavior	Burned Color	Hardness	Ring	Promising for
Yo-1	very low	none made	good	4	good	red	soft	very dead	too siliceous for brick
Yo-2	low	none made	good	8	good	red	soft	very dead	No good, warps on firing
Yo-3	very low	none made	good	1	good	red	soft	very dead	too siliceous
Lu-1	good	good	good	16	bad	red	medium	good	not very promising
Lu-2	fair	none made	fair	8.5	good	red	soft	low	not promising
Lu-3	fair	none made	good	7	good	red	medium	low	common brick
Lu-4	medium	fair	good	11	fair	light red	medium	good	common brick
Mu-1	fair	good	fair	8.5	good	white	hard	fair	whiteware
Mu-2	very low	none made	good	5	good	light choc.	very hard	excellent	face brick
Mu-3	very low	none made	good	4	good	light buff	hard	good	face brick
Mu-4	medium	good	good	12	fair	light red	medium	low	face brick
Mu-5	fair	good	good	9	good	very lt. buff	hard	fair	face brick
Mu-6	very low	none made	good	5	good	light buff	hard	good	face brick
Mu-7	medium	good	bad	15	fair	light red	hard	fair	common brick
Mu-8	fair	good	good	11	good	light red	medium	fair	common brick
Ca-1	low	good	good	8	good	light buff	medium	good	face brick
Ca-2	good	good	bad	10	fair	light red	medium	excellent	not promising
Ca-3	low	good	good	5	good	light buff	medium	excellent	too calcareous
Ca-4	low	none made	good	4	bad	light buff	very soft	fair	too calcareous
Ca-5	good	good	bad	10	fair	light buff	medium	excellent	face brick
Kc-1	low	cracked	good	4	good	light red	soft	fair	common brick
Kc-2	low	cracked	good	8.5		light red	soft	fair	common brick
Kc-3	good	good	bad	12	fair	light red	medium	fair	common brick
Kc-4	good	good	bad	16	fair	buff	medium	fair	common brick
Kc-5	low	good	good	6	good	light red	soft	dead	common brick
N-1	medium	good	good	12	good	buff	medium	good	face brick
N-2	medium	good	good	12.5	good	buff	medium	good	face brick
N-3	medium	good	good	14	good	buff	hard	good	face brick
Wi-1	fair	good	good	10	good	light red	medium	low	common brick
Wi-2—top	medium	good	good	12	good	light red	hard	good	common brick
Wi-2—middle	medium	good	good	10.5	good	light red	medium	good	common brick
Wi-2—bottom	medium	good	good	10	good	buff	hard	fair	common brick
Wi-3—top	good	good	good	10	good	light red	hard	good	common brick
Wi-3—below top	good	good	good	11	good	light red	hard	low	common brick
Wi-3—above bottom	good	good	good	9	good	light red	hard	good	common brick
Wi-3—bottom	fair	good	good	9	good	buff	medium	good	common brick
Ma-1	fair	none made	good	4	good	buff	medium	low	common brick
Ma-2	fair	bad	good	7	fair	red	soft	dead	common brick
Ma-3	low	bad	good	4	fair	red	soft	dead	common brick
Pl-1	good	good	good	10	good	buff	medium	good	face brick
Pl-2	good	good	good	10.5	fair	buff	hard	good	face brick
Pl-3	medium	good	good	10	good	buff	very hard	good	face brick
Pl-4	good	good	good	10	cracked	buff	hard	medium	face brick(?)
Pl-5	good	good	cracked	14	cracked	light red	hard	medium	common brick
Pl-6	good	bad	cracked	11	good	light red	medium	medium	common brick
Pl-7	good	bad	good	12	good	light red	hard	good	not promising (scums)
Pl-8	good	good	good	11	good	red	very hard	good	face brick, tile
H-1	very low	good	good	5	good	light buff	medium	good	common brick
H-2	fair	bad	good	9	good	red	medium	fair	common brick
CC-1	good	good	good	11	good	light buff	very hard	good	face brick
CC-2	fair	bad	good	9	good	buff	medium	good	face brick
CC-3	medium	bad	good	10	good	buff	medium	good	face brick
CC-4	good	good	good	11	bad	buff	hard	good	face brick
CC-5	medium	good	good	12	good	light buff	hard	good	face brick
CC-6	good	good	good	11.5	good	buff	medium	good	face brick
CC-7	good	bad	good	9	good	very light	hard	good	face brick
RP-1	low	bad	good	3.5	good	red	soft	low	common brick
RP-2	good	good	good	12	good	red	hard	fair	common brick
RP-3	good	good	good	13.5	good	red	hard	good	paving brick
RP-4	medium	bad	good	9	good	buff	hard	fair	face brick
RP-5	low	bad	good	4	bad	white, blue flash	slaked	none	no good, lime
RP-6	low	bad	good	6	good	red	soft	dead	common brick
R-1	good	good	good	9	good	light buff	hard	good	face brick
R-2A	fair	bad	good	9	good	light red	medium	good	common brick
R-2B	good	good	good	8	good	light buff	hard	excellent	face brick
R-2C	good	good	good	11	good	buff	hard	good	face brick
R-2D	good	good	good	8	good	buff	hard	good	face brick
R-2E	fair	bad	good	5	good	light red	hard	fair	common brick
R-3	medium	good	good	10	good	light red	hard	fair	common brick
R-4	fair	bad	good	7	good	red	hard	fair	common brick
R-5	fair	bad	good	8	good	light red	hard	good	common brick
R-6	good	good	good	8.5	good	light buff	hard	good	face brick
Fl-2	low	good	good	11	good	red	medium	good	common brick
Fl-3	low	bad	good	9.5	good	red	medium	fair	common brick
Fl-4	very low	bad	good	4.5	fair	red	very hard	good	not promising
Fl-5	medium	bad	small crack	11	good	red	soft	low	common brick
Fl-6	fair	good	good	8	good	red	medium	medium	common brick
Fl-7	good	good	check cracks	15	?	red	hard	good	paving brick
Fl-8	fair	good	check cracks	15.5	?	red	hard	?	common brick
Fl-9	medium	bad	good	7	good	light red	soft	dead	not promising
Fl-10	medium	bad	good	10	good	light red	medium	medium	face brick (?)
Fl-11	fair	bad	cracked	11	good	light red	medium	low	common brick
Go-1	medium	good	bad	14	bad				not promising
Go-2	fair	good	good	8	fair	red	hard	fair	common brick
Go-3	good	good	tender	11	fair	red	hard	good	common brick
Go-4	low	good	good	7	good	light yellow	medium	fair	face brick
Go-5	fair	good	good	12	fair	red	very hard	good	common brick
Fe-1	fair	good	good	8	good	red	very hard	good	tile
Fe-2	low	good	good	10	good	red	medium	fair	common brick
Fe-3	medium	good	good	10	good	pink	very hard	good	face brick
Gd-1	good	good	good	11	fair	red	medium	good	tile or paving brick
A-1	good	good	tender	12	?	buff	hard	good	face brick
A-2	good	good	good	10	good	pink	very hard	good	face brick
AP-1	medium	bad	good	4	bad	light yellow	very soft	dead	common brick
AP-2	medium	bad	good	6	good	cream	hard	medium	face brick

TABLE VI

CHEMICAL ANALYSES OF TEXAS CLAYS, SHALES, ETC., REPRINTED FROM THE UNIVERSITY OF TEXAS BULLETIN 1814, MARCH, 1918.

No.	SiO_2	Al_2O_3	Iron Oxide	MnO	CaO	MgO	K_2O	Na_2O	CO	P_2O_5	SO_3	TiO_2	H_2O	Organic Matter	Total
77	98.80	1.00	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.48		100.28
*78	54.22	11.02	2.16	-----	4.01	1.81	2.19	1.01	1.10	-----	0.19	-----	3.71		99.97
79	10.20	2.13	1.47	-----	45.08	2.22	-----	-----	37.10	-----	0.67	-----	0.62		99.49
80	1.30	0.87	1.13	-----	52.88	0.38	-----	-----	41.19	-----	0.69	-----	1.21		99.65
82	76.00	12.88	1.92	-----	4.53	0.66	-----	-----	0.30	-----	3.57	-----	0.00		99.86
83	61.36	10.61	3.39	-----	6.95	0.93	-----	-----	4.10	-----	0.82	-----	10.46		98.61
84	58.60	11.04	1.92	-----	12.11	0.88	-----	-----	5.80	-----	0.63	-----	7.16		98.14
85	39.16	5.24	2.14	-----	26.11	Trace	-----	-----	19.49	-----	0.96	-----	5.87		98.27
86	52.50	1.41	3.75	-----	21.05	Trace	-----	-----	15.75	-----	1.23	-----	3.65		99.34
†87	50.05	10.15	3.31	0.04	13.94	1.70	1.80	0.54	-----	-----	0.05	-----	16 48		100.08
‡88	67.98	7.90	2.27	0.03	8.98	1.03	1.51	0.63	-----	-----	Trace	-----	9.07		100.21
89	8 10	3.15	3.75	----	41.00	0.47	-----	-----	33.20	-----	-----	-----	6 70		99 67
90	60 96	6.91	4.25	-----	12.00	Trace	1 18	2 00	9.10	-----	-----	-----	3.00		99.40
91	53.60	9.00	2.60	-----	16 80	1.20	1.80	Trace	11.64	-----	-----	0 80	-----		101.16
92	57.38	6.80	2.56	-----	14 31	Trace	1.24	2.22	11.20	-----	-----	-----	-----		99.06
93	34 60	15.02	3.02	-----	21.48	0.15	1.41	1.43	15.60	-----	-----	0.66	6.60		99 60
94	21.36	13.65	32.21	-----	19.00	0.32	0.71	3.39	none	0.61	none	-----	5.52	-----	96.77
95	61.19	16.74	5.99	-----	0 90	-----	1. 31		-----	-----	-----	1 62	12 11	-----	99 86
96	65.60	22.50	1.20	-----	0.70	Tr.	Tr.	1.70	-----	-----	-----	1.10	7 70	-----	100.50
97	74.30	16.00	1.40	-----	Tr.	none	0.50	0.60	-----	-----	-----	0.50	5.07	-----	99.60
98	71.30	19.70	1.00	-----	2.10	Tr.	Tr.	0.08	-----	-----	-----	Tr.	5 80	-----	100.70
99	68.45	21.10	1.10	-----	1.40	Tr.	Tr.	1.25	-----	-----	-----	0.05	6.75	-----	100.10
100	72.70	9.50	1.10	-----	1.10	0.80	2.40	Tr.	-----	-----	-----	0.60	4.50	-----	99.10
101	70.40	17.30	1.80	-----	1 00	Tr.	0.60	2.20	-----	-----	-----	0.60	5.40	-----	99.10
102	47.20	4.10	2.40	-----	21.00	1.40	Tr.	1 30	18.10	-----	-----	0.70	2.90	-----	99.10
103	82.84	3.16	0.75	-----	5.32	0.40	0.90	0.25	4.00	-----	-----	0.20	2.30	-----	99.72
104	65 61	20.48	1.44	----	1.70	0.32	1.00	0.60	-----	-----	-----	0.27	7.50	-----	98 95
105	68.30	20.10	1.00	-----	Tr	2.40	Tr.	0.60	-----	-----	-----	1.20	6.60	-----	100.20
106	68.70	15.90	3.30	-----	3.10	0.50	Tr.	0.30	-----	-----	-----	1.40	5.90	-----	99.10
107	38 08	11.36	2.60	-----	23.70	Tr.	0 58	1.60	-----	-----	-----	0.70	3.06	-----	100.44
108	57.01	11.85	3.02	-----	9.56	1.20	0.75	2.01	-----	-----	-----	1.18	4.00	-----	98.53
109	55.30	13.56	4.50	-----	9.48	none	----	-----	7.45	-----	none	-----	-----	8.85	99.14
110	50.47	18.24	4.77	-----	4.30	Tr.	Tr.	0.21	3.25	-----	0.90	1.14	5.70	0.55	98.56
111	66.72	24.42	Tr.	-----	0.42	Tr.	Tr.	Tr.	-----	-----	Tr.	-----	7. 94		99.50
112	71 20	18.00	0.60	-----	Tr.	2.00	0.90	0 30	-----	-----	-----	0.95	5.80	-----	99.58
113	88 71	14.88	2.00	-----	0.30	0.97	Tr.	Tr.	-----	-----	----	0.90	2.28	-----	100.04
114	73.61	17.01	0.50	-----	0.08	1.36	Tr.	0.15	-----	-----	-----	1 57	6.00	-----	100.15
115	66.01	18.82	6.33	-----	0 55	1.88	0.16	0.08	-----	-----	-----	0.95	4.80	-----	99 58
116	76.17	8 33	2.99	-----	0.60	0.55	0.80	-----	0.47	0.083	0.106	-----	5.82	3.94	99.86

*Contained water at 100°, 23 per cent.
†Contained water at 100°, 1.94 per cent.
‡Contained water at 100°, 0 81 per cent.

TABLE VI (Continued)

No.	SiO_2	Al_2O_3	Iron Oxide	MnO	CaO	MgO	K_2O	Na_2O	CO_2	P_2O_5	SO_3	TiO_2	H_2O	Organic Matter	Total
117	68.56	18.53	0.72	-----	0.60	0.12	2.27	2.72	-----	-----	-----	0.43	7.00	-----	100.95
118	72.64	12.11	3.45	-----	1.46	0.23	1.40	1.70	-----	-----	-----	-----	7.20*	-----	100.21
119	64.1[illegible]	18.81	6.05	-----	0.74	0.30	1.28	0.58	-----	-----	-----	-----	8.70†	-----	-----
120	4.54	0.75	1.40	-----	52.01	0.24	-----	-----	40.70	-----	-----	-----	0.50	-----	100.07
121	19.34	3.00	2.16	-----	39.50	1.00	-----	-----	31.50	-----	-----	-----	2.30	0.90	99.70
122	51.96	12.40	4.60	-----	12.50	1.40	1.50	2.40	8.50	-----	-----	0.70	5.50	-----	101.40
123	64.16	23.57	5.39	-----	0.12	0.18	0. 40		-----	-----	-----	-----	6. 22		100.04
124	19.36	7.88	0.92	-----	38.88	0.40	none	none	30.44	-----	-----	-----	1. 08		98.90
125	49.4[illegible]	22. 67		-----	9.20	-----	-----	-----	-----	-----	0.96	-----	24 55‡	-----	99.93
126	85.60	6.71	1.44	-----	Tr.	0.43	0 50	0.65	-----	-----	-----	1.00	3 10	-----	99.43
127	72.70	14 46	3 81	-----	0 08	1.03	Tr	Tr	-----	-----	-----	1.43	4.61	-----	99.08
128	25.80	42.20	19.75	-----	0.90	0.80	0.26	2.50	-----	0.49	-----	-----	none	-----	92.70
129	82 47	10 92	1.08	-----	0.22	0 96	none	none	-----	-----	-----	1.00	2.47	-----	99.10
130	45.07	15.78	4.92	0.02	7.98	1.18	1.70	0.08	-----	-----	9.71	-----	6.51	6 89	99.84
131	56.71	19.74	5.74	0.02	1.28	1.91	1.67	0.30	-----	-----	0.25	-----	4.00	8.62	100.30
132	57.26	18.45	8.25	-----	1.52	none	-----	-----	1.20	-----	none	-----	13. 00		99.68
133	57 26	22 00	1.67	-----	1 97	1 41	0 67	0 61	1 88	-----	0 00	1 33	6 24	2 70	100 0
134	58.70	21.73	5.49	-----	1.06	1.24	0 32	0 18	-----	-----	0 33	1.13	5.88	3.00	99.06
135	55.10	23 80	3.51	-----	3.28	1.24	0.50	0.21	1.75	-----	3.37	1.05	6.00	-----	99.81
136	53.80	23.24	3.60	-----	1.76	1.44	1.65	2.00	0.80	-----	-----	1.40	6.04	3.36	99.09
137	53.21	22.83	6.48	-----	1.70	1.72	Tr.	0.05	3.10	-----	-----	1.75	7.06	2.00	99.90
138	53.48	14.70	6.24	-----	8.08	1.14	0.85	1.60	4.66	-----	-----	1.00	6.90	-----	99.01
139	69.50	15.60	2 37	-----	2 38	2 00	0.77	0 87	-----	-----	-----	1.20	5.00	-----	99.84
140	70.00	18.70	1.20	-----	0.50	1.20	Tr.	1.50	-----	-----	-----	1.00	6.10	-----	100.20
141	57.0	25.5[illegible]	3.4	---	0 [illegible]	0.72	0.94	0.82	-----	-----	-----	1.87	10.00	-----	100.34
142	51.50	17.60	16.60	-----	1.08	1.10	1.50	Tr.	-----	-----	-----	1 60	7.70	-----	98.60
143	56.20	23.70	1.50	-----	0 60	1.50	1.40	2.20	-----	-----	-----	1.60	11.10	-----	99.80
144	51.90	17.30	4.50	-----	10 08	1.90	Tr.	3.60	6.50	-----	-----	Tr.	4.90	-----	100.60
145‖	42.40	16.82	7.50	-----	10.82	1.60	-----	-----	-----	-----	7.20	-----	12.72	-----	-----
146	62.36	22.63	3.71	-----	0.20	0.21	1.41	1.73	-----	-----	-----	1.13	6.82	-----	100.26
147	49.60	16.06	5.60	-----	10.06	2 14	1.38	0.77	6.91	-----	1.12	0.70	5 02	-----	99.39
148	47.92	14.40	3 60	-----	12.30	1.08	1.20	1.50	9.50	-----	1.44	1.22	4.87	1.34	100.35
149	49 08	10.90	7.74	0.11	13.56	1.36	1.26	0.20	none	-----	0.22	-----	1.59	14.37	100.39
150	55.54	15.72	6.96	0.13	4 88	2 43	1 64	0 51	none	-----	0.28	-----	2.63	9.25	99.97
151	75 15	13.76	2.37	0.04	0.66	0.15	0 96	0 15	none	-----	0.45	-----	0 58	5.48	99.93
152	58.73	20.71	4.67	0.05	2.65	1 71	1.76	0.05	none	-----	0.44	-----	0.80	8.91	99.82
153	53 66	12.97	5.63	-----	9 13	1.21	0.70	0 80	7.41	-----	0.57	-----	-----	7.59	99.97
154	68.75	15.81	4.05	-----	0 60	1.61	Tr	0 08	-----	-----	-----	0 60	4.67	2.10	97.70
155	64.72	17.72	4.46	-----	0.27	1.58	2.71	1.24	-----	-----	none	1.30	5.44	-----	99.24
156	63.07	19.43	4.75	-----	1.32	0.70	none	none	-----	-----	0.15	1.47	6 90	-----	99.09
157	69.50	13.00	4.40	-----	2.46	0.97	1.18	0.99	1.93	-----	0.63	-----	-----	5.31	100.37
158	68.60	20.47	0.72	-----	Tr.	0.40	1.33	0.25	-----	-----	-----	1 1[illegible]	6.26	-----	99 16
159	73.00	15.79	0.63	Tr.	1.29	1.53	0 10	0.16	-----	-----	-----	0.43	5.76	-----	98.69
160	83.80	9 23	2.30	-----	Tr.	Tr.	0 56	0 54	-----	-----	-----	0.87	3.10	-----	100.40
161	73.16	13.86	1.44	-----	3.14	1.61	Tr.	0 23	-----	-----	-----	0.70	5.15	-----	99.29
162	74.82	13 61	0.72	-----	1.69	2.02	Tr.	0.27	-----	-----	-----	0 39	5.67	-----	98.19
163	37.05	8.13	1.80	-----	2.23	0.08	0.47	Tr.	22.12	-----	-----	0.47	2.64	-----	99.82
164	41.20	6.50	1.98	-----	1 62	0.14	0 43	0.09	20.63	-----	-----	0.43	2.28	-----	99.27
165	75.41	12.49	0.72	-----	1.82	1.80	0.29	0.56	-----	-----	-----	0.19	5.93	-----	99.21
166	57 78	17.11	Tr.	-----	2.70	1.86	1. 12		-----	-----	-----	none	19 85	-----	100 42
167	76.00	11.36	0.72	-----	1 96	1.58	0.58	0.86	-----	-----	-----	Tr.	6.20	-----	99.26
168	59.34	15.71	5.76	-----	3.00	2 00	0.56	1.44	1.07	-----	0.31	1.83	7.02	2.00	100.13
169	73.06	9 88	6.92	-----	1.50	0.27	Tr.	0.12	-----	-----	-----	1.00	6.61	-----	99.37
170	68.50	18.41	3.02	-----	0.70	1.05	0.47	0.91	-----	-----	-----	1.31	6.20	-----	100.57
171	58.50	18.39	3 21	-----	2.34	1.61	2.70	4.93	-----	-----	Tr.	-----	8 20		99 88
172	68.56	18.53	0.72	-----	0.60	0.12	2.27	2.72	-----	-----	-----	0.43	7.00	-----	100.95

*4 60 combined water, 2.00 Hygroscopic.
†2 50 combined water, 6.00 Hygroscopic.
‡7 25 combined and 17.30 Hygroscopic.
‖1 66 soluble in water

TABLE VI (Continued)

No.	SiO_2	Al_2O_3	Fe Oxide	MnO	CaO	MgO	K_2O	Na_2O	CO_2	P_2O_5	SO_3	TiO_2	H_2O	Organic Matter	Total
173	40.69	12.68	3.90	-----	18.12	0.92	1. 14		-----	-----	-----	none	22.55	-----	100.00
174	72.30	19.33	2.47	-----	Tr.	0.50	4. 44		-----	-----	-----	none	none	-----	99.04
175	18.62	3.23	1.26	-----	11 30	0.12	-----	-----	32.50	-----	-----	-----	2.42	-----	99.75
176	83.41	7.20	2.26	-----	0.78	0.45	Tr.	0.12	-----	-----	-----	0.66	3.58	-----	98.46
177	72.45	11.72	3.38	-----	3.66	1.34	Tr.	9.19	-----	-----	-----	0.87	3.44	-----	97.05
178	49.40	17.90	4.50	-----	9.50	1.88	none	Tr.	9.55	-----	-----	1.05	4.58	-----	98.36
179	68 90	21.83	1.57	-----	-----	-----	2. 00		-----	-----	-----	-----	5.60	-----	99.90
180	83 90	5.52	4.75	-----	0.40	1.82	0.15	0.15	-----	-----	-----	1.57	2.44	-----	100.50
181	73.11	17.77	2.83	-----	0.40	0 28	2.76	3.02	-----	-----	-----	-----	-----	-----	100.17
182	74.15	14.11	4.03	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
183	68 35	16.22	4.08	-----	-----	1.08	2. 20		-----	-----	-----	-----	8.09	-----	99.93
184	-----	-----	-----	-----	-----	-----	3.20	2 90	-----	-----	-----	-----	-----	-----	-----
185	71.00	20.20	2.20	-----	Tr.	Tr.	1 24	6 16	-----	-----	-----	-----	-----	-----	100.80
186	65.90	18 43	3.77	-----	0.60	0.30	0.95	4.08	-----	-----	-----	-----	6.36	-----	100.39
187	82 10	14.24	1.56	-----	1.15	-----	-----	§1.00	-----	-----	-----	-----	-----	-----	-----
188	68.90	21.83	1.57	-----	-----	-----	6 60	4.00	-----	-----	-----	-----	-----	-----	-----
189	75.30	13.87	2.53	-----	1.90	1.23	2.62	2.65	-----	-----	-----	-----	-----	-----	100.10
190	71.11	17.85	0.28	-----	0.05	0.41	0.36	0.68	-----	-----	-----	1.45	6.31	-----	98.50
191	72.30	19 33	2.47	-----	Tr.	0.50	Tr.	4.44	-----	-----	-----	-----	-----	-----	99.04
192	61.90	23.70	5.50	-----	Tr.	1.11	Tr.	1.27	-----	6.52	-----	-----	-----	6.52	100.00
193	62 12	25.11	0.30	-----	0.33	0 21	Tr.	0.10	-----	-----	-----	2.12	10 00	-----	100.29
194	60 88	20 47	0 21	-----	0 50	0 30	0 15	0.33	-----	-----	-----	1.10	6.68	-----	98 92
195	74 04	15.15	0.50	-----	0.50	0.27	0 42	1.12	-----	-----	-----	1.31	6 00	-----	99.81
196	77.20	15.29	1.59	-----	0.33	Tr.	Tr.	0.12	-----	-----	-----	1.18	4.75	-----	100.55
197	68.55	26.00	Tr.	-----	Tr.	0.11	Tr.	Tr.	-----	-----	-----	-----	6. 00		100.66
198	69.20	21.06	1.37	-----	Tr.	0.94	Tr	2.30	-----	-----	-----	-----	5. 16		100.00
199	70 80	18 56	1.04	-----	Tr.	1.58	Tr.	5.35	-----	-----	-----	-----	2. 60		99.93
200	74.03	17.10	0.57	-----	0.10	0.22	0.30	0.60	-----	-----	-----	1.36	6.15	-----	100.43
201	69 36	14.67	4.46	-----	0.28	1.74	1.55	2.09	-----	-----	-----	1.13	3.64	0.96	99.88
202	77.70	10.37	9.33	-----	1.70	Tr.	0.24	0.54	-----	-----	-----	-----	-----	-----	99.78
203	42 10	19 82	15.48	-----	6 66	0.44	-----	-----	5.26	-----	0.11	-----	9. 84		100.01
204	20 12	14.30	42.10	-----	11.21	0 72	0.62	1.58	-----	0 58	-----	-----	6.10	-----	106.33
205	79 00	11.38	2.44	-----	0 50	0.20	0 35	0.65	-----	-----	-----	0 78	3 80	-----	99.00
206	77 97	11 01	3.19	-----	0 81	0 38	none	none	-----	-----	0.51	1.23	3.21	-----	98.40
*207	41 40	8 60	3.57	-----	6 80	-----	-----	-----	-----	-----	3 75	-----	-----	-----	-----
208	67 00	17 61	3.67	-----	Tr.	1.32	0.68	1.57	-----	-----	0 53	2.10	5.20	1.03	100 73
209	64 20	20.13	1.87	-----	0 34	1 62	0.69	1 78	Tr.	-----	1.80	2.60	5.32	1 00	100.75
210	81 50	5.13	3.60	-----	1.30	0.25	0 49	1 56	-----	-----	-----	0.87	4.00	-----	99.00
211	67.20	12 48	3.52	-----	5.78	0.25	-----	-----	4 54	-----	1.17	-----	-----	4.96	99.90
212	77 40	12 70	0 70	-----	-----	-----	-----	-----	-----	-----	-----	0 70	70	-----	100 20
213	70.82	18.90	0.40	-----	Tr.	Tr.	Ti.	0.50	-----	-----	-----	2.10	6.80	-----	99.52
214	62.10	20.66	8.54	-----	0.40	Tr.	1.12	7.77	-----	-----	-----	-----	-----	-----	100.89
215	76.00	9.45	4.75	-----	Tr.	none	2.00	4.00	-----	-----	-----	-----	4.70	-----	100.90
216	58.20	23.97	4.43	-----	-----	-----	7. 11		-----	-----	-----	none	5.36	-----	99.07
217	51.22	20.34	6.82	-----	7.94	Tr.	0. 14		6.23	0.02	none	-----	1.05	-----	93.56
218	72 36	7 84	1.72	-----	6.48	2.23	1.20	1 70	3.30	-----	-----	0.12	3.72	-----	100.67
219	71.40	8.20	2.30	-----	6 34	2.44	1.22	1 60	3.25	-----	-----	0.14	3.70	-----	100.59
220	57.60	19.34	6.14	-----	1.23	2.01	2.02	2.73	-----	-----	-----	-----	1.70	7.09	99.86
221	67.20	13.50	-----	-----	2.00	-----	1.16	0.11	1.65	-----	0.75	-----	-----	13.25	99.72
222	51.12	11.04	4.10	-----	14.24	0 90	0.40	1.59	10.62	-----	-----	0.95	4.00	-----	98.97
223	67.00	19 68	0.72	-----	0.62	1.06	Tr.	0.18	-----	-----	-----	1.82	6.07	-----	97.15
224	77.00	15.87	1.26	-----	1.10	0.37	none	none	-----	-----	-----	0 87	4.50	-----	100.97
225	64.00	22.59	1.22	-----	0.88	1.15	Tr.	0.06	-----	-----	-----	1.51	5.80	-----	97.21
226	57.40	28.84	0.72	-----	0.10	0.10	Tr.	0.47	-----	-----	-----	1.48	10.44	-----	99.55
227	60.33	19.38	1.07	-----	0.87	0.86	Tr.	0.12	-----	-----	-----	1.40	5.46	-----	98.49
228	72.90	14.70	4.50	-----	0.60	0.30	1.50	0 70	-----	-----	-----	1.00	4.20	-----	99.50
229	75.33	14.73	1.10	-----	0.07	1.61	0.64	0.10	-----	-----	-----	1.27	4.50	-----	99.30
230	55.28	21.27	8.37	-----	3.90	0.28	none	Tr	3.30	-----	-----	1.05	4.26	1.43	99.14

§ as Chlorides.
*Silver 65 oz. per ton; copper 11.8 per cent.

TABLE VI (Continued)

No.	SiO_2	Al_2O_3	Iron Oxide	Mn O	Ca O	Mg O	K_2O	Na_2O	CO_2	P_2O_5	SO_3	Ti O_2	H_2O	Organic Matter	Total
231	46.60	33 66	-----	-----	0.43	0.96	1. 65		-----	-----	-----	-----	4.53	-----	87.83
232	82.80	9.83	2.77	-----	Tr	ace	1.62	3.84	-----	-----	-----	-----	-----	-----	100.86
233	72.00	11.82	3.38	-----	Tr	ace	2.57	5.56	-----	-----	-----	-----	5.70	-----	101.03
224	57.80	18.84	7.55	-----	Tr	ace	1.05	5.62	-----	-----	-----	-----	9.01	-----	99.97
235	79.00	5.54	5.66	-----	Tr	ace	0.66	5.38	-----	-----	-----	-----	4.56	-----	100.74
236	83.40	6.45	4.40	-----	Tr	ace	1.33	3.87	-----	-----	-----	-----	-----	-----	99.45
237	73.60	-----	-----	-----	Tr	ace	2.33	4.75	-----	-----	-----	-----	-----	-----	-----
238	79.20	6.12	2.51	-----	Tr	ace	1.33	6.09	-----	-----	-----	-----	4.70	-----	100.15
239	55.25	19 80	4.60	-----	0.73	4.51	2 21	1.73	4.17	-----	-----	1.31	4.78	0.91	100.00
240	70.00	18 60	4.50	-----	Tr.	Tr.	Tr.	0.90	-----	-----	-----	0.60	6.10	-----	100.70
241	68.34	15.28	3.44	-----	1.20	0.88	2.47	3.55	-----	-----	-----	0.52	4.70	-----	100.38
242	78.50	10.50	3.60	-----	0.45	0.23	0.90	0.40	-----	-----	-----	0.32	4.22	-----	99.12
243	83.50	8.51	1.40	-----	1.00	1.08	0.50	1.50	-----	-----	-----	1.05	2.40	-----	100.94
244	83.00	7 42	0.36	-----	Tr.	3.01	0.30	1.26	-----	-----	-----	0.70	3.70	-----	99.75
245	64.40	24 17	3.23	-----	Tr.	Tr.	-----	3.50	-----	Tr.	-----	-----	7.25	-----	-----
246	7.40	55 00	4.40	-----	6 58	8.28	2.57	5.26	-----	Tr.	0.73	-----	13.50	-----	99.72
247	73 00	6.91	5.69	-----	Tr.	0.50	2.62	2.50	-----	-----	-----	-----	9.00	-----	100.22
248	62.00	12.12	5.08	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
249	71.25	18 58	1.62	-----	Tr.	0.60	-----	4.00	-----	-----	Tr.	-----	5.50	-----	-----
250a	69.80	15.85	1.60	-----	3.40	0.53	0.50	1.05	-----	-----	-----	0.17	6 72	-----	99.62
250b	74.04	7.50	4.16	-----	4.37	-----	0.79	0.66	-----	-----	0.17	-----	9.10	-----	100.79
251	62.70	17.97	6.94	-----	0.92	0.60	1.53	0.86	-----	-----	0.44	0.24	8.05	-----	100.25
252	64.00	24 17	3 23	-----	Tr.	Tr.	3. 50		-----	-----	-----	-----	7.25	-----	102.15
253	85.40	10 02	2.18	-----	0.10	none	Tr	ace	-----	-----	-----	-----	1.95	-----	99.65
254	78.22	8 71	0.72	-----	3.36	1.10	0 45	1.17	-----	-----	-----	0.17	5.50	-----	99.40
255	50.20	20 90	5.10	-----	8.93	-----	-----	-----	7.02	-----	1.88	-----	-----	6.08	100.11
256	58 48	18.23	7.54	-----	1.24	3.83	1.15	2.88	-----	-----	-----	1.05	5.46	-----	99.86
257	36 08	18.64	4.14	0.01	17.39	1.74	1.49	0.19	-----	-----	1.59	-----	3.09	15.77	100.13
258	26 18	9 66	3.55	0.07	28 15	1.28	1.06	0.12	-----	-----	1.20	-----	2.65	26.66	100.38
259	17.81	6.10	2.04	0.02	34.76	1.27	0.50	1.60	-----	-----	0.92	-----	1.81	32.95	99.78
260	17.56	7.60	1.76	0.02	32.59	1.28	1.74	0.40	-----	-----	1.08	-----	1.82	34.08	99.93
261	16.30	6.97	1.65	0.02	36.03	1.29	1.78	0 30	-----	-----	0.89	-----	1.81	36.03	99.91
262	36.28	13.60	1.44	0.01	16.42	3.83	0.64	0.22	-----	-----	0.16	-----	7.52	20.07	100.19
263	51.01	18.23	3.51	0.02	8.87	1.54	2.16	0.08	-----	-----	1.03	-----	2.72	11.04	100.21
264	40 38	18.69	3.62	0.03	9.74	3.10	0.77	0.70	-----	-----	0.27	-----	8.21	14.63	100.15
265	41.20	16.12	3 41	0.05	16.36	1.26	1.44	0 24	-----	-----	0.28	-----	2.32	17.50	100.18
266	42.56	15.34	5.28	0 04	14.26	1.01	1 21	0.57	-----	-----	0.47	-----	2.25	17.29	100.28
267	40.86	14.92	6.10	0.04	14.81	0.70	1.48	0.22	-----	-----	0.86	-----	1.72	18.56	100.27
268	38 42	16.95	5 07	0 02	14.86	0.83	1 64	1.04	-----	-----	0.39	-----	2.59	18.59	100.40
269	37 64	13.80	6.00	0.06	17.18	0.79	1.28	0.72	-----	-----	0.48	-----	2.56	19 86	100.37
270	42.10	15.90	3.35	0.07	15.33	0.36	2.03	0.23	-----	-----	0.82	-----	2.57	17.37	100.13
271	29 48	12.25	2 69	0 12	26.32	0.82	1.61	0.16	-----	-----	0.07	-----	2.17	24.61	100.30
272	32.91	13.42	2.69	0.12	23.61	0.97	1.73	0.15	-----	-----	0.92	-----	1.70	21.97	100.20
273	42.00	17.78	2 46	0 01	14.24	0.98	0.83	1.05	-----	-----	1.06	-----	1.96	17.82	100.28
274	40 70	15.50	3 24	0 07	16.41	0.71	1.97	0 38	-----	-----	0.81	-----	2.21	18.17	100.26
275	41.63	15.55	3.57	0.07	15.68	0.98	1.66	0.20	-----	-----	0.74	-----	2.97	17.00	100.05
276	90.06	4.60	1.44	-----	0.10	0.10	Tr.	Tr.	-----	-----	-----	0.70	3.04	-----	99.98
277	68 11	20 08		-----	-----	-----	2.63	2.18	-----	-----	-----	-----	00.00	-----	92.99
278	50.67	00 00	23.53	-----	00.00	00.00	2.63	2.22	-----	00.00	00.00	-----	-----	-----	-----
279	75.29	0.00	0.00	-----	0 00	0 00	2.93	0.30	-----	0.00	0.00	-----	-----	-----	-----
280	51.30	14 40	6 29	-----	10.30	Tr.	Tr.	4.10	7.60	-----	-----	0.80	4.90	-----	99.60
281	67.18	13.96	1.25	-----	1.94	1.36	1.43	2.77	-----	-----	-----	-----	10. 06		99.95
282	61.56	19.25	1.65	-----	1.10	0.79	1. 86		-----	-----	-----	-----	13.79	-----	100.00
283	60.41	22 43	1.90	-----	0.44	0 61	0.45	0.24	-----	-----	-----	1.30	6.00	6.50	100.28
284	59 03	11.19	2 77	-----	12.16	0 80	Tr.	0.18	9.60	-----	-----	1.05	2.10	-----	98.88
285	63 00	23 00	2.50	-----	Tr	1.10	1.70	0.30	-----	-----	-----	1.30	-----	-----	97.70
286	63.43	23.12	1.15	-----	0.45	1.23	0.07	0.26	-----	-----	-----	1.13	-----	0.40	98.54
287	57.00	22.20	2.10	-----	0 25	Tr	Tr.	0.21	-----	-----	-----	1.31	16. 65		99.72
288	58.22	21.10	1.85	-----	1.08	0.10	0.05	0.18	-----	-----	-----	1.48	14. 42		98 48
289	65 92	10.57	1.94	-----	9 33	1.23	-----	-----	7.06	-----	-----	0.90	2.65	-----	100.20
290	63 56	8.18	4.32	-----	10.00	0.15	Tr.	1.00	7.30	-----	-----	0.95	4 16	-----	99.68
291	65.07	9.16	2.80	-----	8 44	0.21	0.50	1.66	0.92	-----	-----	1.05	3.72	-----	99.53

TABLE VI (Continued)

No.	SiO_2	Al_2O_3	Iron Oxide	Mn O	Ca O	Mg O	K_2O	Na_2O	CO_2	P_2O_5	SO_3	TiO_2	H_2O	Organic Matter	Total
292	15.98	8.	47	-----	38.86	-----	0.15	2.84	31.74	0.108	0.83	------	1.10	------	-------
293	60.87	16 05	5.25	-----	3 66	-----	1 75	2.94	2 85	0 187	1.06	------	5.35	------	99.917
294	45 92	16.17	4.78	----	14.26	none	0.975	3.22	10.30	0.113	0.97	------	4.36	------	100.23
295	48 72	16.10	4 87	-----	11.79	Tr.	1.14	3.07	8.30	0.109	2.21	------	3.68	------	99.99
296	28.34	7.50	3.92	-----	29.76	none	0.29	2.01	22.80	0.118	1.04	------	3.77	------	99.58
297	37.45	7.72	2.02	-----	27.92	0.36	------	------	21.80	------	------	Tr.	2.40	------	99.67
298	21.72	7.97	2.23	-----	36.51	0.95	Tr.	Tr.	28.44	------	------	0.52	2.06	------	99.73
299	73.15	20 46	Tr.	-----	none	Tr.	Tr.	Tr.	------	------	------	Tr.	------	6. 37	99.98
300	68 84	21 15	1.15	-----	Tr.	Tr.	0 45	1.12	------	------	------	1.22	6.62	------	100.55
301	70.50	18 30	1.80	-----	Tr.	0.90	Tr.	0.20	------	------	------	1.20	5 5'	------	98.40
302	37.45	7 72	2.02	-----	27.92	0.36	------	------	21.80	------	------	------	2.40	------	99.67
303	59.20	20.60	6.90	-----	1.08	1.62	1.60	1.84	------	------	------	1.50	4.66	0.20	99.20
304	56.01	24 67	2.59	-----	Tr.	1.11	1.19	1.44	------	------	------	1.50	7.30	4.04	99.40
305	63.30	23.40	1.60	-----	Tr.	0.30	0.90	1.00	------	------	------	1.20	7.60	------	99 30
306	71.78	16.75	1 11	-----	0.32	1.17	0.19	0.86	------	------	------	1.15	5.90	------	99.23
307	67.65	20.50	1.20	-----	Tr.	0 25	1 05	0.50	------	------	------	1.30	6.60	------	99.05
308	60 90	20.95	5.30	-----	0.05	0.25	1.85	1.40	------	------	------	0 80	6.30	------	100.50
309	63 30	24.50	1.30	-----	0.10	0.20	2.30	1.30	------	------	------	1.00	8.70	------	100.10
310	60.50	19.40	9.30	-----	Tr.	0.30	1.40	1.50	------	------	------	0.60	9.30	------	99.50
311	54.80	20 48	2.22	-----	7.74	0.80	------	------	6 09	------	0.55	------	------	6.71	99.39

KAOLIN

No.	Silica	Al_2O_3	Fe_2O_3	Ca O	Mg O	K_2O	Na_2O	C O_2	H_2O (comb)	H_2O (Hyg.)	Total
1091	76.36	17.00	0.46	0.64	------	------	------	------	6.30	------	100.76
1092	45.50	33.23	0.60	------	------	------	------	------	12.50	6.42	98.26
1093	48 41	43.17	------	0.38	0.10	1. 78		------	6.05	------	99.89
1094	45.04	32.90	2.73	------	------	------	------	1.80	8.28	4.97	98.45
1095	45.52	42.30	------	Trace	------	------	------	------	13.92	------	100.74
1096	45.00	33.50	1.50	1.00	0.30	------	------	------	18.20	------	99.50

ABBREVIATIONS FOR SOURCES OF ANALYSES

U.T.B.=University of Texas Bulletin (Official Series).
U.T.M.S.B.=University of Texas Mineral Survey Bulletin.
T.M.S.A.N.=Texas Mineral Survey Analyses No. taken from the office files of The University of Texas Mineral Survey.
T.A.E.S.A.R.=Texas Agricultural Experiment Station Annual Report.
T.G.S.A.R.=Texas Geological Survey Annual Report.
T.G.S.A.=Texas Geological Survey Analysis taken from the office files of the Texas Geological Survey.
B.A.=Bureau Analysis:—Analyses taken from the office files of The University of Texas Bureau of Economic Geology. Those in which the numbers are preceded by capital "C" are from the files of the new Division of Chemistry of the Bureau; e. g., B.A., C135.
T.A.S.=Texas Academy of Science (Proceedings).
U.S.G.S.W.S.=United States Geological Survey Water Supply Paper.
U.S.G.S.A.R.=United States Geological Survey Annual Report.
U.S.G.S.B.=United States Geological Survey Bulletin.

List of analysts referred to in the following pages, with the initials by which they are designated.

P.H.B.=P. H. Bates.
J.H.H.=J. H. Herndon.
O.H.P.=O. H. Palm, Chemist, The University of Texas Mineral Survey, 1901–1904.
G.A.P.=G. A. Parkinson, Assistant Testing Engineer, Road Materials Laboratory, The University of Texas 1914–.
E.L.P.=E. L. Porch, Jr., Assistant Geologist, Bureau of Economic Geology, The University of Texas, 1914–1917.
J.E.S.=J. E. Stullken, Chemist, Bureau of Economic Geology and Technology, and Bureau of Industrial Chemistry, 1913–.
S.H.W.=S. H. Worrell, Chemist, Bureau of Economic Geology, 1910–1914.

Anal. No.

77. Atascosa County. Alluvium, received from E. E. Baird, from S. A. U. & G. Ry., north of Pleasanton. Marked "Atascosa River Sand" Analyzed 1915 by J.E.S. B.A. 2668.

78. El Paso County. Alluvium from White's Spur, ten miles above El Paso. Analyzed by P.H.B. U.S.G.S.B. 340, p. 413.

79. Hays County. Adobe with gravel. Sample received from Deshay Bunton. From hill 2½ miles north of Kyle on the San Antonio-Austin road, near two-story house. Sampled by G.A.P. Analyzed 1914 by J.E.S. B.A. 2034.

80. Hays County. Adobe from about 1 mile north of Kyle on the Buda-Kyle Mountain Road, about ¾ mile west of the I. & G. N. Ry. Exposure good. Sampled by G.A.P. Analyzed 1914 by J.E.S. B.A. 2016.

82. La Salle County. Alluvium (adobe) from Dobson, sent in by E. R. Breaker. Proposed to be used for ballast. Analyzed 1914 by J.E.S. B.A. 2041.

83. Live Oak County. Alluvium (adobe) from Fant City. Sent in by E. R. Breaker, Pleasanton, Texas. Labelled "Adobe Shale." Has given good service as ballast. Analyzed 1914 by J.E.S. B.A. 2040.

84. Live Oak County. Alluvium (adobe) from Fant City. Sample sent in by E. R. Breaker, proposed to be used as ballast. Analyzed 1914 by J.E.S. B.A. 2039.

85. San Patricio County. Alluvium (adobe) from near Mathis, sent in by E. R. Breaker of Pleasanton, Texas. Analyzed 1914 by J.E.S. B.A. 2038.

86. San Patricio County. Alluvium (adobe) from near Mathis. Sample sent in by E. R. Breaker, Chief Engineer of the S. A. U. & G. Ry., Pleasanton. Proposed to be used as ballast. Analyzed 1914 by J.E.S. B.A. 2037.

87. Travis County. Alluvium (Pleistocene). Heavy calcareous clay used in making dry pressed brick at Butler's brick yard, south side of Colorado River, near I. & G. N. Ry., Austin, Texas. U.S.G.S.B. 522, p. 342.

88. Travis County. Alluvium (Pleistocene). Same as No. 87, except light loamy clay used in making sand-mould brick. U.S.G.S.B., 522, p. 342.

89. Travis County. Alluvium, 300–400 yards above Pease Park, on banks of Shoal Creak, near city of Austin. Analyzed 1914 by J.E.S. B.A. 1974.

90. Travis County. Alluvium, from A. J. Zilker, Austin. Labelled "Dry Pressed Brick Clay." Analyzed 1905 by O.H.P. T.M.S.A. 3440.

91. Travis County. Calcareous brick clay (alluvium), from Butler's brick yard, Austin. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 204.

92. Travis County. Alluvium, from A. J. Zilker, Austin. Labelled "Mud Brick Clay." Analyzed 1905 by O.H.P. T.M.S.A. 3439.

93. Travis County. Alluvium (calcareous brick clay), from Belcher's place, Austin. U.T.B. 102, p. 206.

94. Anderson County. Marl from 1 mile south of Elkhart. T.G.S.A.R. I, p. 94.

95. Bastrop County. Shale (Eocene tertiary), 2½ miles from Elgin, near M. K. & T. Ry. Analyzed 1904.

96. Bastrop County. Fire clay from Elgin. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 77.

97. Bastrop County. Pottery clay (Eocene tertiary), from 3 miles north of McDade. Analyzed 1914. U.T.B. 365, p. 62.

98. Bastrop County. Fire clay from near Elgin. Analyzed 1908 by O.H.P. and S.H.W. U.T.B. 102, p. 77.

99. Bastrop County. Fire clay (Eocene tertiary), from near Elgin. U.T.B. 365, p. 62.

100. Bastrop County. Sandy brick clay (Eocene tertary), from Elgin. Analyzed by O.H.P and S.H.W. U.T.B. 365, p. 63.

101. Bastrop County. Red and brown burning clay from Elgin. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 62.

102. Bell County. Calcareous clay, from Belton. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 214.

103. Bell County. Same locality, etc., as No. 102.

104. Bexar County. Pottery clay from Stromberg. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 143.

105. Bexar County. Pottery clay from 2½ miles west of Elmendorf. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 143.

106. Bexar County. Red and brown burning clay, from Adkins. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 68.

107. Bexar County. Easily fusible clay, from south side of Leon Creek, near San Antonio, between crossing of dirt road and I. & G. N. Ry., 15 feet thick. U.T.B. 102, p. 266.

108. Bexar County. Easily fusible clay, on Alazan Creek, 1¼ miles north of I. & G. N. Ry. depot, San Antonio. U.T.B. 102, p. 276.

109. Bexar County. Shale, from near San Antonio. Used by the San Antonio Portland Cement Co. in making cement. Located on I. & G. N. Ry. 5 miles north of San Antonio. University museum specimen No. 1165. Analyzed 1914 by J.E.S. B.A. 1997.

110. Bexar County. Clay, from Bem Brick Co., near San Antonio. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 171.

111. Bexar County. Clay from near Elmendorf. Analyzed 1903 by S.H.W. T.M.S.A. 2052.

112. Bowie County. Red and brown burning clay, from near Boston. U.T.B. 365, p. 74.

113. Bowie County. Sandy brick clay, from Texarkana. U.T.B. 365, p. 74.

114. Bowie County. Fire clay, from near Boston. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 101.

115. Bowie County. Red and brown burning clay, from New Boston. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 184.

116. Brazos County. Clay, from college farm at College Station. T.A.E.S.B. 25, p. 269.

117. Brazos County. Easily fusible clay, from 12 miles southeast of College Station. U.T.B. 365, p. 76.

118. Brewster County. Clay (Upper Cretaceous), from Chisos Beds in Chisos Country, west of Chisos Mountains. U.T.B. 93, p. 63.

119. Brewster County. Clay (Tornillo formation), from Chisos Country, east side of Rough Run, about 2 miles east of Dogis Mountain. Analyzed by O.H.P. U.T.B. 93, p. 56.

120. Brewster County. Chalky clay, from the Chisos Country. Terlingua Beds, west of Chisos Pens. Analyzed by O.H.P. U.T.B. 93, p. 40.

121. Brewster County. Chalky clay, from Chisos Country. Terlingua Beds, south of Cuesta Blanca. Analyzed by O.H.P. U.T.B. 93, p. 40.

122. Brewster County. Calcareous clay from Terlingua. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 214.

123. Brewster County. Clay from N. & S. vein, section 39, Terlingua Mining Co., Terlingua. Analyzed 1902 by O.H.P. T.M.S.A. 1629.

124. Brewster County. Clay, stratified vein material, N. & S. vein, section 39, Terlingua Mining Co., Terlingua. Analyzed 1902 by O.H.P. T.M.S.A. 1640.

125. Caldwell County. Clay, sample received from E. L. Porch, marked "Outcrop near drilling location in eastern end of Caldwell County, near Gonzales County line." Analyzed 1915 by J.E.S. B.A. 2644.

126. Chambers County. Sandy brick clay, from Cedar Bayou. U.T.B. 365, p. 91.

127. Cherokee County. Sandy brick clay, from Rusk. U.T.B. 365, p. 92.

128. Cherokee County. Marl, green clay stratum in greensand bed of Cherokee County. T.G.S.A.R. I, p. 94.

129. Cherokee County. Buff burning and semi-refractory clay (Eocene tertiary), from Rusk. U.T.B. 365, p. 91.

130. Dallas County. Shale (Upper Cretaceous, Eagle Ford), from quarry of Texas Portland Cement Co., Dallas. U.S.G.S.B. 522, p. 343.

131. Dallas County. Same location, etc., as No. 130.

132. Dallas County. Shale, used in making cement, by the Texas Portland Cement Co., near Dallas. Analyzed 1914 by J.E.S. B.A. 1998.

133. Dallas County. Red and brown burning clay (Upper Cretaceous), from West Dallas. U.T.B. 365, p. 104.

134. Dallas County. Red and brown burning clays (Upper Cretaceous), from West Dallas. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 192.

135. Dallas County. Same location, etc., as No. 134.

136. Dallas County. Same location, etc., as No. 134.

137. Dallas County. Red and brown burning clay, same location as No. 134.

138. Delta County. Red and brown burning clay, from Cooper. U.T.B. 365, p. 106.

139. Denton County. Pottery clay, near Denton. U.T.B. 365, p. 107.

140. Denton County. Pottery clay, near Lloyd. U.T.B. 365, p. 107.

141. Denton County. Buff burning and semi-refractory clay, top layer, from near Denton. U.T.B. 365, p. 107. Viscous at Cone 14.

142. Denton County. Buff burning and semi-refractory clay, middle layer. Denton. U.T.B. 365, p. 107. Steel hard at Cone 8.

143. Denton County. Buff burning and semi-refractory clay. Denton. U.T.B. 365, p. 107. Vitrified at Cone 14.

144. DeWitt County. From 840 feet in drill hole, at Cuero. Analyzed 1904 by S.H.W. T.M.S.A. No. 2527.

145. Dickens County. Shale from Spur well, Spur. Depth 2042 to 2047 feet. Received from Dr. J. A. Udden. Analyzed 1914 by S.H.W. B.A. 1325.

146. Eastland County. Clay from Lone Star Coal Co., Cisco. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 186.

147. Ellis County. Red and brown burning clay, from Ferris. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 192.

148. Ellis County. Red and brown burning clay. Same locality, etc., as No. 147.

149. El Paso County. Shale (Lower Cretaceous), ¼ mile south of Courchesne Quarry, El Paso, Texas. U.S.G.S.B. 522, p. 413.

150. El Paso County. Shale (Lower Cretaceous), ¼ mile north of Courchesne Quarry, El Paso U.S.G.S.B. 522, p. 413.

151–152. El Paso County. Shale from El Paso Brick Co.'s property. U.S. G.S.B. 522, p. 413.

153. Erath County. Shale. Sample received from W. J. Gordon, of Thurber, marked "Upper one foot underlying limestone." Analyzed 1915 by J.E.S. B.A. 2523.

154. Erath County. Red and brown burning clay from Thurber. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 118.

155–156. Erath County. Clay for paving brick, from Thurber. Analyzed by O.H.P. U.T.B. 102, p. 248.

157. Erath County. Shale, sample received from W. J. Gordon, of Thurber, marked "Mixture of lower 5 feet of shale underlying limestone." Analyzed 1915 by J.E.S. B.A. 2522.

158. Falls County. Pottery clay, from Denny. U.T.B. 365, p. 119.

159. Fayette County. Fire clay from property of Mr. Lytenburg, southeast of Lena. Analyzed 1908 by O.H.P. and S.H.W. U.T.B. 102, p. 276.

160. Fort Bend County. Sandy brick clay (Quaternary), from Wilson plantation, Fulshear. U.T.B. 365, p. 125.

161. Gonzales County. Clay (Eocene tertiary), from Harwood's property, 6 miles southeast of Gonzales. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 278.

162. Gonzales County. Clay from same locality as No. 161. Anallyzed by O.H.P. and S.H.W. U.T.B. 102, p. 281

163. Gonzales County. Calcareous clay (Eocene tertiary), Gonzales. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 214.

164. Gonzales County. Calcareous clay, from same locality as No. 163. U.T.B. 102, p. 214.

165. Gonzales County. White clay, from Harwood property, 6 miles southeast of Gonzales. Average of two analyses. U.T.B. 365, p. 130.

166. Gonzales County. Clay from Sunset Brick and Tile Co., Gonzales. Analyzed by O.H.P. T.M.S.A. 1801.

167. Gonzales County. Clay from Sunset Brick and Tile Co., Gonzales. Analyzed by O.H.P. T.M.S.A. 2696.

168. Grayson County. Red and brown burning clay from Sherman. U.T.B. 365, p. 132.

169. Gregg County. Sandy brick clay, Longview. U.T.B. 365, p. 133.

170. Gregg County. Sandy brick clay, Longview. U.T.B. 365, p. 133.

171. Grimes County. Brick clay, near Piedmont Springs. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 287.

172. Grimes County. Clay, 13 miles northeast of Navasota. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 270.

173. Grimes County. Sandy brick clay from Courtney. Analyzed by O.H.P. and S.H.W. Min. Ind. 1893, Vol. II, p. 210.

174. Guadalupe County. Sandy brick clay from Morrison. Min. Ind. 1893, Vol. II, p. 210.

175. Guadalupe County. Calcareous brick clay from Seguin. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 135.

176. Harris County. Sandy brick clay from Center Bayou. U.T.B. 365, p. 139.

177. Harris County. Red and brown burning clay (Quaternary) from Houston. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 139.

178. Harris County. Red and brown burning clay (Quaternary). Locality, etc., same as No. 177.

179. Harrison County. Pottery clay (Eocene tertiary) from along road from Marshall to Jefferson. U.T.B. 365, p. 140.

180. Harrison County. Sandy brick clay (Eocene tertiary) from Marshall. U.T.B. 365, p. 140.

181. Harrison County. Clay (Eocene tertiary) from A. Dean headright. Analyzed in laboratory of Texas Geol. Survey by J.H.H. and L.E.M. U.T.B. 102, p. 291.

182. Harrison County. Clay (Eocene tertiary) from J. Sanchez headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

183. Harrison County. Clay (Eocene tertiary) from F. Wilson headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

184 Harrison County. Clay (Eocene tertiary) from D. McGray headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

185. Harrison County. Clay (Eocene tertiary) from P. Whetstone headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

186. Harrison County. Clay (Eocene tertiary) from D. McGray headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

187. Harrison County. Clay (Eocene tertiary) from F. Wilson headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

188. Harrison County. Clay (Eocene tertiary) from Lewis Watkins headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

189. Harrison County. Clay (Eocene tertiary) from M. L. Rager headright. Analyzed by J.H.H. and L.E.M. U.T.B. 102, p. 291.

190. Henderson County. Pottery Clay. Average of two analyses of samples from Athens. U.T.B. 365, p. 143.

191. Henderson County. Clay (Eocene tertiary) for ornamental brick and tiles. From Henry Morrison pit near Athens. T.G.S.A.R. II, p. 199.

192. Henderson County. Clay (Eocene tertiary) for ornamental brick and tiles, from J. B. Attwood Survey near Athens. T.G.S.A.R. II, p. 199.

193. Henderson County. Fire clay (Eocene tertiary) from Malakoff. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 97.

194. Henderson County. Fire clay (Eocene tertiary) from Malakoff. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 97.

195. Henderson County. Fire clay (Eocene tertiary) from near Athens. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 94.

196. Henderson County. Fire clay (Eocene tertiary) from near Athens. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 96.

197. Henderson County. Refractory clay (Eocene tertiary) just west of town of Athens. T.G.S.A.R. II, p. 197.

198. Henderson County. Pottery clay from T. Murchison farm west side of B. Attwood headright, ½ mile north and a little east of Athens. T.G.S.A.R. II, p. 198 (1890).

199. Henderson County. Pottery clay from brook on Bishop farm on Boly C. Walter's headright, 1 mile north of Athens. T.G.S.A.R. II, p. 198 (1890).

200. Hopkins County. Fire clay from near Sulphur Springs. Ries Analysis No. 870. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 99.

201. Hopkins County. Red and brown burning clay from Sulphur Springs. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 182.

202. Houston County. Red burning clay (Eocene tertiary) from Hurricane Bayou on N. C. Hodge headright. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 295.

203. Houston County. Marl (Eocene tertiary). Sample from Major W. J. Borden, United States Engineer, Dallas. Marked "No. 2 hard pan or soft rock found at Hurricane Shoals, Trinity River, 243 miles below Dallas, and 90 miles above Riverside." Analyzed 1915 by J.E.S. B.A. 2698.

204. Houston County. Marl (Eocene tertiary). Fourteen miles east of Crockett. T.G.S.A.R. I, p. 94.

205. Hunt County. Red and brown burning clay (Upper cretaceous) from Greenville. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 149.

206. Jefferson County. Red and brown burning clay (Quaternary) from Beaumont. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 153.

207. Jones County. Cupriferous clay from the Avoca Area. Analyzed by H. Tobelmann. *Economic Geology,* Vol. 10, p. 642.

208. Lamar County. Red and brown burning clay from Paris. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 192.

209. Lamar County. Sample and locality, etc., similar to No. 208. Reference identical.

210. Lee County. Sandy brick clay (Eocene tertiary) from Giddings. U.T.B. 365, p. 163.

211. Leon County. Clay (Eocene tertiary). Sample received from Bear Grass Coal Co., of Jewett. Marked "Three-foot strata in 18-ft. deposit." Analyzed 1915 by J.E.S. B.A. 2575.

212. Limestone County. Fire clay from Headsville. U.T.B. 365, p. 166.

213. Limestone County. Fire clay from Headsville. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 92.

214. Marion County. Clay (Eocene tertiary) from Thos. Farrell's bank, A. Richardson headright, near Jefferson. U.T.B. 102, p. 297.

215. Marion County. Clay (Eocene tertiary) from J. Higgins' yard, near Jefferson. U.T.B. 102, p. 298.

216. Marion County. Pottery Clay. *Mining Industry,* Vol. II, p. 210 (1893).

217. McLennan County. Marl (Upper cretaceous) from Waco. T.M.S.A. No. 1440.

218. McLennan County. Red and brown burning clay (Upper cretaceous) from Waco. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 173.

219. McLennan County. Calcareous clay from Waco. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 214.

220. McCulloch County. Clay from Canyon Division of Brownwood bed, 1½ miles northeast of Milburn. T.C.S.A.R. No. 4 (for 1892), p. 440: Paper by N. F. Drake, "Report of Colorado Coal Field of Texas."

221. McMullen County. White clay (Siliceous sinter, Eocene tertiary) from 12 miles north of Tilden. Analyzed 1916 by J.E.S. B.A. 2988.

222. Medina County. Calcareous brick clay (Upper cretaceous) from D'Hanis. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 180.

223. Milam County. Fire clay from Vogel's Mine, Rockdale, clay under lignite. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 161.

224. Milam County. Fire clay (Eocene tertiary). Top clay from Olsen's Mine, Rockdale. Analyzed by O.H.P. U.T.B. 102, p. 158.

225. Milam County. Fire clay (Eocene tertiary) under lignite in Olsen's Mine, Rockdale. Analyzed by O.H.P. U.T.B. 102, p. 159.

226. Milam County. Fire clay from near Milano Junction. Analyzed by O.H.P. U.T.B. 102, 89.

227. Milam County. Fire Clay from Rockdale. U.T.B. 365, p. 182.

228. Milam County. Fire clay from Rockdale. Analyzed by OH..P. U.T.B. 365, p. 182.

229. Nacogdoches County. Pottery clay from Nacogdoches. U.T.B. 365, p. 186.

230. Navarro County. Red and brown burning clay (Upper cretaceous) from Corsicana. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 188.

231. Nueces County. Clay. Analyzed 1890 by Dr. Edgar Everhart. T.G.S.A.R. II, p. 51.

232. Panola County. White sandy clay (Eocene tertiary) on Carthage and Timpson Road, 2 miles south of Carthage. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 300.

233. Panola County. Gray sandy clay, above lignite shale on Allen Baker farm, M. Payne headright, 4 miles east of Carthage. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 300.

234. Panola County. Plastic ferruginous clay, 1 mile east of Tatum Station. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 300.

235. Panola County. Red and gray mottled clay, under iron bed, Six Mile Creek. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 300.

236. Panola County. Indurated sandy clay, Donnel Field, ½ mile southeast of Carthage. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 300.

237. Panola County. Lignitic clay shale, lower bed near Iron Bayou, Lagrone headright. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 300.

238. Panola County. Stiff, tenacious clay, sandy soil, light brown color, from lignitic series in plowed field, R. W. Kenard farm, Daniel Martin headright. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 300.

239. Parker County. Pottery clay from Rock Creek, about 15 miles west of Weatherford. U.T.B. 365, p. 197.

240. Polk County. Sandy brick clay from Hortense. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 200.

241. Polk County. Easily fusible clay from near Carmona. U.T.B. 365, p. 200.

242. Red River County. Sandy brick clay from Detroit (Upper cretaceous formation). U.T.B. 365, p. 205.

243. Robertson County. Clay from Calvert. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 269.

244. Robertson County. Fire clay from Bremond. U.T.B. 365, p. 207.

245. Rusk County. Gray clay, lignitic series (Eocene tertiary), used at Henderson pottery, ½ mile north of courthouse at Henderson. U.T.B. 102, p. 302.

246. Rusk County. Indurated glauconitic clay (Eocene tertiary) from greensand marl series near Sulphur Springs, 18 miles south of Henderson. U.T.B. 102, p. 302.

247. Rusk County. Micaceous sandy lignitic clay, 18 miles south of Henderson. U.T.B. 102, p. 302.

248. Rusk County. Mottled orange loam, Lower Orange Sand Formation, on hillside, northern exposure at Millville. U.T.B. 102, p. 302.

249. Rusk County. Dark gray, slightly magnesian, pocket bed Lignitic Series on Larissa Road, 8 miles west of Henderson. U.T.B. 102, p. 302.

250-a. Rusk County. Pottery clay from near Henderson. U.T.B. 365, p. 209.

250-b. San Patricio County. Clay. From land owned by R.A. Arnold, ½ mile west of Portland. B.A. No. C286. Analyzed by J.E.S. 1916.

251. Shackelford County. Clay (Permian), average of 6 analyses, from Black Ranch, 10 to 12 miles north of Albany. U.T.B. 365, p. 215.

252. Smith County. Pottery clay, near Garden Valley. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 304.

253. Smith County. Same as No. 252, except that sample came from near Tyler.

254. Smith County. Pottery clay from Liebrich Pottery Co., near Tyler. U.T.B. 365, p. 217.

255. Tarrant County. Calcareous clay shale from Washita Division of the Comanchean formation, from property of the O. K. Cattle Co., about 4 miles east of Tarrant County courthouse. Analyzed 1915 by J.E.S. B.A. 2748.

256. Tom Green County. From San Angelo. Analyzed by S.H.W. U.T.B. 102, p. 268.

257. Travis County. Marl (Taylor marl division of the Lower cretaceous), on east bank of Big Walnut Creek, 2 miles below Sprinkle and 6½ miles northeast of Austin. U.S.G.S.B. 522, p. 342.

258. Travis County. Marl (Taylor marl division of the Lower cretaceous), from wagon road on hill, just west of Little Walnut Creek, 4½ miles northeast of Austin and 1 mile north of Pecan Springs. U.S.G.S.B. 522, p. 342.

259. Travis County. Clay shale (Eagle Ford of Lower cretaceous), from south side of Big Walnut Creek 9½ miles northeast of Austin and 1½ miles below Watters Station. U.S.G.S.B. 522, p. 342.

260. Travis County. Limy shale (Eagle Ford of the Lower cretaceous), from 8 feet of bed below middle of Eagle Ford clay from bluff of small creek near I. & G. N. Ry., 1 mile south of Colorado River near Austin. U.S.G.S.B. 522, p. 342.

261. Travis County. Limy shale (Eagle Ford of the Lower cretaceous), upper 10 feet of Eagle Ford clay from bluff of small creek near I. & G. N. Ry., 1 mile south of Colorado River near Austin. U.S.G.S.B. 522, p. 342.

262. Travis County. Clay (Webberville formation) from Wilbarger Creek, 3 miles below Manor. U.S.G.S.B. 522, p. 342.

263. Travis County. Clay (Del Rio formation of the Lower cretaceous), from bluff on Barton Creek, ½ mile above its mouth, sampled above and below wagon road near bridge. U.S.G.S.B. 522, p. 342.

264. Travis County. Clay (Webberville formation, Lower cretaceous), from Moore's Branch of Onion Creek, 9 miles southeast of Austin. U.S.G.S.B. 522, p. 342.

265–275. Travis County. Clays (Del Rio formation of the Lower cretaceous) for cement manufacture, from property of the Austin Portland Cement Co., 3½ miles northwest of the center of Austin. Depth of strata 10 to 20 feet. U.S.G.S.B. 522, p. 341.

276. Tyler County. Sandy brick clay from Colmesneil. U.T.B. 365, p. 232.

277. Van Zandt County. Clay (Eocene tertiary) from well 10 miles northeast of Canton. T.G.S.A.R. I, p. 94.

278 and 279. Van Zandt County. Clay marl (Eocene tertiary) from Grand Saline Station on T. & P. Ry. T.G.S.A.R. I, p. 94.

280. Washington County. Calcareous clay from Brenham. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 214.

281. Washington County. Clay from Tatum Farm, near Burton. Analyzed by T. B. Tucker. U.S.G.S.B. 470, p. 318.

282. Washington County. Clay from Elliott's Farm, near Burton. Analyzed by W. W. Camp of Denver, Colo. U.S.G.S.B. 470, p. 323.

283. Webb County. Buff burning, semi-refractory clay from Minera. U.T.B. 365, p. 241. Vitrified at Cone 12.

284. Webb County. Calcareous brick clay (Eocene tertiary) from Laredo. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 242.

285. Webb County. Shale from under coal at Minera, near Laredo. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 153.

286. Webb County. Shale beneath coal at Minera. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 153.

287. Webb County. Shale under lower or San Pedro seam at Cannel, near Laredo. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 153.

288. Webb County. Weathered shale from the lower seam or San Pedro seam at Cannel. Used for dry pressed bricks at Laredo. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 153.

289. Wharton County. Calcareous brick clay, from Wharton. Analyzed by O.H.P. U.T.B. 102, p. 214.

290. Same as No. 289.

291. Same as No. 289.

292. Williamson County. Chalk-marl (Upper cretaceous) from San Gabriel River. U.S.G.S.A.R. III, p. 737. (?)

293. Williamson County. Greensand marl (Upper cretaceous). From beneath I. & G. N. Ry. bridge over Brushy Creek. Analyzed by G. H. Wooten. T.G.S.A.R. III, p. 355.

294. Williamson County. Taylor marl (Upper cretaceous) from lower portion of Taylor marl bed Brushy Creek, ½ mile southeast of Taylor. Analyzed by J. A. Taff. U.S.G.S.A.R. XXI, Part VII, p. 337.

295. Williamson County. Taylor marl (Upper cretaceous) from central portion of Taylor marl bed at Rice's crossing, Brushy Creek. Analyzed by J. A. Taff. U.S.G.S.A.R. XXI, Part VII, p. 337.

296. Williamson County. Taylor marl (Upper cretaceous) from Taylor marl bed at Rice's Crossing on Brushy Creek. Analyzed by J. A. Taff. U.S.G.S.A.R. XXI, Part VII, p. 337.

297. Wilson County. Calcareous clay from Calaveras. Analyzed by O.H.P. and S.H.W. U.T.B. 102. p. 214.

298. Williamson County. Calcareous clay from Taylor. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 214.

299. Wilson County. Fire clay from near Sutherland Springs. Analyzed 1903 by S.H.W. T.M.S.A. No. 2053.

300. Wilson County. Pottery clay from Lavernia. U.T.B. 365, p. 249.

301. Wilson County. Buff burning, semi-refractory clay from Calaveras. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 249.

302. Wilson County. Calcareous brick clay from Calaveras. Analyzed by O.H.P. and S.H.W. U.T.B. 365, p. 249.

303. Wise County. Easily fusible clay from Bridgeport. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 272.

304. Wise County. Red and brown burning clay from Bridgeport. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 188.

305. Wood County. Pottery clay, from 5 miles east of Winnsboro, used by the Winnsboro pottery. Analyzed by S.H.W. T.M.S.A. No. 2508.

306. Wood County. Pottery clay. Average of two analyses of samples from Cornersville. U.T.B. 365, p. 253.

307. Wood County. Pottery clay. Average of two analyses of samples from Winnsboro. U.T.B. 365, p. 253.

308. Young County. Sandy brick clay (vitrifiable) from 14 miles west of town of Graham. U.T.B. 365, p. 255.

309. Young County. Paving brick clay. From land of H. K. Graham, near Graham. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 245.

310. Young County. Paving brick clay from tank 14 miles west of Graham. Analyzed by O.H.P. and S.H.W. U.T.B. 102, p. 247.

311. Shale from bed of Trinity River, near Texas Midland Ry. bridge, about 50 miles below Dallas. Sample received from W. J. Barden, U. S. Engineer. Analyzed by J.E.S., 1915. B.A. 2697.

KAOLIN

1091. Culberson County. Sample from Dr. J. A. Udden, marked "The Conder Cut plateau No. 3, about 3 miles west of Boracho." Analyzed 1913 by S.H.W. B.A. 960.

1092. Edwards County (now Real County). Cleaned and ground kaolin from the mill at Godbold's house, near Leakey. Analyzed 1913 by J.E.S. B.A. 584.

1093. Edwards County (Real County). Analyzed by Dr. Everhardt of The University of Texas, 1890. T.G.S.A.R. II, p. LI.

1094. Edwards (Real) County. Ground but not cleaned kaolin from mill at Godbold's house, near Leakey. Analyzed 1913 by J.E.S. B.A. 585.

1095. Uvalde County. From Thornton's ranch, 15 miles north of Uvalde, from hole alongside creek in arroyo. Sampled by E.L.P. Analyzed 1914 by S.H.W. B.A. 1440.

1096. Uvalde County. 15 miles north of Sabinal on Big Blanco Creek. Sample from Russell Myrick, San Antonio. Analyzed by J.E.S. B.A. 1268.

REPORTS FROM SAN ANTONIO CHAMBER OF COMMERCE

The table which follows presents in condensed form the results of a number of ceramic tests made under the supervision of the Industrial Department of the San Antonio Chamber of Commerce. This organization, with the assistance of the San Antonio Public Service Company, the Central Power and Light Company, and the J. E. Jarratt Company, equipped its own testing laboratory and employed a ceramist for the purpose of testing a large number of clay samples obtained mainly from the territory adjacent to San Antonio. A list of all samples thus examined, together with the conclusions drawn from the tests and a general report of the work of the ceramic laboratory, has been published in pamphlet form by the San Antonio Chamber of Commerce under date of December, 1929, and this pamphlet may be obtained from that organization. There are also complete records of these tests on file at that office, and all persons interested in these clays for commercial purposes may obtain the information contained in these files. Samples of these raw clays and of burned test pieces made from these clays may be seen on application.

Only the more representative samples and the more important observations with regard to these samples are included in the following table. In the last column the uses for which the samples were judged to be suitable is shown together with a rough classification into grades A, B, and C. The classifications and other observations were made by the ceramist making the tests. All these tests were made by Mr. A. V. Lawton, who was in the employ of the San Antonio Chamber of Commerce at the time that this work was done.

It is considered that these records are a valuable addition to the ceramic information presented in this bulletin. Mr. C. C. Leel, Industrial Secretary of the San Antonio Chamber of Commerce, has kindly given permission for the printing of this material in this bulletin.

Abbreviations employed in this table are as follows:

b.=buff
bl.=black
br.=brown
choc.=chocolate
cr.=cream
d.=dark
F.=fair
fu.=fused
G.=good
gr.=gray
grn.=green
l.=light
o.=orange
P.=poor
r.=red
sl.=slight
V.=very
vit.=vitrified
wh.=white
y.=yellow

LIST OF SAMPLES DISCUSSED

Explanation of Sample Numbers

Samples numbered 801 to 960, inclusive, are those which are discussed in Dr. Ries's bulletin ("The Clays of Texas," U. T. Bull. No. 102, 1908). These numbers are Dr. Ries's original laboratory numbers. Ceramic tests of these samples are tabulated in numerical order in Table I facing page 168. Chemical analyses are likewise tabulated in Table II facing page 168, and the samples are enumerated and described separately on pages 168 to 175.

Samples whose numbers are preceded by the capital letter C are those which have been examined by the Bureau of Industrial Chemistry since 1918. Some of these have been analyzed chemically and these analyses are given in Table III on page 176. Others have been given ceramic tests and the results of these tests are given in Table IV on pages 177 to 187. All samples are then enumerated and discussed separately on pages 188 to 196.

Samples designated by lower case letters of the alphabet and listed on pages 196 and 197 were given preliminary or partial ceramis tests by the Bureau of Industrial Chemistry.

Samples designated by one or two letters and a number, separated by a hyphen, such as Ca-1, RP-1, or H-2, were given preliminary ceramic tests, and these results are given in Table V facing page 198.

Samples numbered 77 to 311, inclusive, and 1091 to 1096, inclusive, were analyzed chemically by various parties and the analyses collected and printed in University Bulletin No. 1814, March, 1918. These records are reprinted here because of the information on Texas resources which they contain. The numbers employed are those by which they were designated in the bulletin above referred to. These chemical analyses are tabulated in numerical order in Table VI on pages 199 to 203 and the samples are enumerated and described separately on pages 204 to 215.

Samples whose numbers are preceded by the letters SA were examined by Mr. A. V. Lawton in the ceramic laboratory of the San Antonio Chamber of Commerce, and extracts from his reports on these samples are printed here by courtesy of the Industrial

Department of that organization. These extracts are found in Table VII facing page 216.

List of Samples According to Class of Clay

High Grade Clays (Kaolin, etc.)—833, C1156, C1366, C1367, C1368, C1441, C1442, C1443, C1511, Mu-1, 1091(?), 1092, 1093, 1094, 1095, 1096, SA21, SA24. SA25, SA26, SA40, SA60, SA67, SA73, SA74, SA104, SA105, SA114, SA175, SA212, SA225, SA231, SA234, SA235, SA236.

Fire Clays—849, 850, 851, 852, 870, 874, 923, 952, 954, 955, 956, C672(?), 1, 99, 197, 212, 227, 244, 299.

Semi-refractory Clays—814, 815, 829, 854, 861, 926, 929, 957, C1352, C1439, C1440, 129, 283, SA112, SA149, SA222, SA243, SA333, SA380.

Pottery and Stoneware Clays—807, 808, 845, 853, 854, 855, 858, 972, 913, 925, 927, 928, 929, 932, 933, 948, 953, 960, C1124, C1125, C1126, C1127, 97, 139, 158, 179, 190, 198, 199, 229, 239, 250, 254, 300, 306, 307, SA239, SA240, SA360, SA361.

Buff Burning Brick Clays.—801, 802, 803, 804, 805, 806, 809, 810, 814, 815, 816, 817, 818, 827, 829, 842, 843, 844, 855, 856, 858, 861, 880, 906, 911, 944, 958, C1520, C1814, C2149, C2570, Mu-3, Mu-5, Mu-6, Ca-1, Ca-5, Kc-4, N-1, N-2, N-3, Wi-1, Wi-2, Wi-3, Ma-1, Pl-1, Pl-2, Pl-3, Pl-4, H-1, CC-2, CC-3, CC-4, CC-5, CC-6, CC-7, RP-4, R-1, R-2, R-3, R-6, Fc-3, A-1, A-2, AP-2, 129, 141, 142, 143, 283, SA6, SA7, SA8, SA16, SA17, SA18, SA19, SA32, SA36, SA58, SA62, SA80, SA86, SA88, SA110, SA111, SA116, SA119, SA146, SA157, SA170, SA179, SA199, SA208, SA211, SA237, SA244, SA255, SA289, SA324, SA325, SA359, SA390, SA405, SA416, SA417, SA422.

Red and Brown Burning Brick Clays—811, 821, 823, 825, 830, 834, 835, 836, 837, 838, 839, 840, 841, 846, 848, 857, 860, 863, 865, 866, 869, 875, 876, 878, 879, 891, 904, 905, 907, 914, 915, 921, 933, 937, 943, 946, 959, C1128, C1129, C1130, C1131, C1132, C1133, C1134, C1135, C1158, C1160, C1358, C1381, C1382, C1383, C1384, C1438, C1439, C1440, C1512, C1528, C1603, C1605, C1676, C1980, C2162, C2635, C2994, C2995, C2996, C2997, C2998, C2999, C3000, b, g, Lu-3, Lu-4, Mu-2, Mu-4, Mu-7, Mu-8, Ca-1, Kc-2, Kc-3, Kc-5, Wi-1, Wi-2, Wi-3, Ma-2, Ma-3, Pl-5, Pl-6, Pl-7, Pl-8, H-2, RP-1, RP-2, RP-3, RP-6, R-2, R-3, R-4, R-5, Fl-2, Fl-3, Fl-4, Fl-6, Fl-7, Fl-8, Fl-9, Fl-10, Fl-11, Go-2, Go-3, Go-5, Fc-1, Fc-2, Gd-1, 112, 134, 154, 168, 191, 192, 218, 230, SA9, SA14, SA22, SA23, SA29, SA30, SA31, SA33, SA34, SA48, SA49, SA51, SA53, SA54, SA57, SA61, SA69, SA89, SA97, SA118, SA124, SA128, SA131, SA132, SA133, SA134, SA159, SA171, SA173, SA184, SA198, SA201, SA204, SA205, SA219, SA223, SA230, SA247, SA248, SA249, SA250, SA251, SA252, SA254, SA256, SA268, SA271, SA287, SA293, SA294, SA295, SA296A, SA297, SA303, SA330, SA366, SA421.

Calcareous Brick Clays—801, 806, 809, 813, 901, 902, 903, 910, 918, 919, 945, C1482, C1483, 87, 90, 92, 222.

Sandy Brick Clays—806, 821, 824, 826, 830, 865, 866, 904, 907, 909, 920, 922, 937, 947, C1158, C1160, C1347, C1352, C1383, C1384, 88, 100, 113, 126, 127, 160, 169, 170, 176, 180, 210, 240, 242, 276, 308, SA126.

Vitrifiable Brick Clays—848, C2162, 308, RP-3, Fl-7, Gd-1, SA100, SA101, SA176, SA181, SA193, SA195, SA386, SA424.

Clays of Easy Fusibility—871, 873, 877, 880, 930, 949, 950, 951, 117, 241, SA13, SA47.

Clays on which Unfavorable Reports were made—831, 832, C1029, C1136, C1159, C1161, C1265, C1266, C1267, C1380, C2097, C2098, c. d, f, Yo-1, Yo-2, Yo-3, Lu-1, Lu-2, Ca-2, Ca-3 Ca-4, Pl-7, RP-5, Fl-4, Fl-9, Go-1, SA2, SA3, SA4, SA5, SA55, SA56, SA59, SA64, SA65, SA72, SA87, SA90, SA99, SA102, SA103, SA115, SA117, SA120, SA121, SA122, SA123, SA127, SA129, SA130, SA145.

SA147, SA151, SA152, SA154, SA155, SA158, SA160, SA161, SA162, SA163, SA164, SA177, SA178, SA194, SA202, SA203, SA206, SA214, SA216, SA241, SA242, SA253, SA285, SA286, SA299, SA321, SA323, SA327, SA356, SA391.

List of Clays According to Counties

Anderson: g, 94.
Angelina: C1054.
Aransas: RP-1, RP-2, RP-3, RP-4, RP-5, RP-6.
Atascosa: 77, SA2, SA3, SA4, SA5, SA29, SA30, SA31, SA33, SA34, SA36, SA48, SA49, SA55, SA56, SA57, SA64, SA65, SA89, SA151, SA170, SA171, SA175, SA211, SA223, SA240, SA241, SA405.
Bastrop: 956, 957, 958, 959, 960, 95, 96, 97, 98, 99, 100.
Bee: SA330.
Bell: 918, 919, 102, 103, k.
Bexar: 809, 811, 815, 925, 926, 949, C902(?), C1605, A-1, A-2, 104, 105, 106, 107, 108, 109, 111, SA14, SA23, SA47, SA69, SA72, SA90, SA99, SA100, SA101, SA102, SA103, SA110, SA111, SA112, SA117, SA118, SA126, SA133, SA134, SA149, SA157, SA162, SA163, SA173, SA176, SA177, SA184, SA186, SA193, SA201, SA202, SA206, SA208, SA216, SA219, SA222, SA239, SA299, SA336, SA359, SA360, SA361, SA366, SA386, SA390, SA416, SA417, SA422, SA424.
Bowie: 858, 860, 861, 112, 113, 114, 115.
Brazoria: C1156.
Brazos: C1383, C1384, C1803, 116, 117, SA324.
Brewster: 877, C1185, 118, 119, 120, 121, 122, 123, 124.
Burleson: C672.
Burnet: C1845, C1846, C1847.
Caldwell: Lu-1, Lu-2, Lu-3, Lu-4, 125, SA104, SA105, SA268.
Cameron: C1094, f.
Camp: C1132, C1133, C1134, C1135, C1136.
Chambers: 866, 126.
Cherokee: 856, 857, C1123, C1124, C1125, C1126, C1127, C1128, C1129, 127, 128, 129.
Coleman: C1159, C1160, C1161, C1381, C1382.
Collin: C875.
Colorado: C1944, C1949.
Comal: SA127, SA178, SA179, SA323.
Crosby: c.
Culberson: 1091.
Dallas: 836, 837, 838, 841, 130, 131, 132, 133, 134, 135, 136, 137.
Delta: 921, 138.
Denton: 842, 843, 844, 845, 913, 139, 140, 141, 142, 143.
DeWitt: 144, SA97, SA194.
Dickens: 145.
Dimmit: SA293, SA294, SA295.
Eastland: 943, 944, C1109, 146.
Edwards: SA154.
Ellis: 839, 840, 147, 148.
El Paso: 78, 149, 150, 151, 152.
Erath: 846, 848, 153, 154, 155, 156, 157.
Falls: 943, 158.
Fayette: 831, 832, Fl-2- Fl-3, Fl-4, Fl-5, Fl-6, Fl-7, Mu-1, Mu-2, Mu-3, Mu-4, Mu-1, Mu-6, Mu-7, Mu-8, N-1, N-2, N-3, Wi-1, Wi-2, Wi-3, 159, SA24, SA58, SA59, SA60, SA61, SA321, SA380.
Fort Bend: 937, 160.
Frio: C1334, C2097, C2098, SA128, SA129.
Gillespie: SA370.

Temperature Equivalents

Wherever temperatures are given throughout this bulletin they are stated either in degrees on the Centigrade scale or in Cones of the standard series of pyrometric cones. When it is desired to express a temperature, given in Centigrade degrees, in Fahrenheit degrees, it is simply necessary to multiply the Centigrade number by the number 1.8 and to add 32 to the product. In order to convert temperatures given in Cone numbers to degrees of either scale, or vice versa, the following table is used:

Cone Number	Degrees Fahrenheit	Degrees Centigrade	Cone Number	Degrees Fahrenheit	Degrees Centigrade
022	1094	590	8	2354	1290
021	1148	620	9	2390	1310
020	1202	650	10	2426	1330
019	1256	680	11	2462	1350
018	1310	710	12	2498	1370
017	1364	740	13	2534	1390
016	1418	770	14	2570	1410
015	1472	800	15	2606	1430
014	1526	830	16	2642	1450
013	1580	860	17	2678	1470
012	1634	890	18	2714	1490
011	1688	920	19	2750	1510
010	1742	950	20	2786	1530
09	1778	970	21	2822	1550
08	1814	990	22	2858	1570
07	1850	1010	23	2894	1590
06	1886	1030	24	2930	1610
05	1922	1050	25	2966	1630
04	1958	1070	26	3002	1650
03	1994	1090	27	3038	1670
02	2030	1110	28	3074	1690
01	2066	1130	29	3110	1710
1	2102	1150	30	3146	1730
2	2138	1170	31	3182	1750
3	2174	1190	32	3218	1770
4	2210	1210	33	3254	1790
5	2246	1230	34	3290	1810
6	2282	1250	35	3326	1830
7	2318	1270	36	3362	1850

METHODS OF TESTING CLAYS

The methods of testing clays have been studied by the American Ceramic Society with a view to establishing uniform standards. The standard and tentative methods decided upon have been printed in the publications of this society, and can be obtained from the publication office located in Easton, Pennsylvania.

The equipment necessary for making the tests can be had from various manufacturers, all of whom advertise their products in the trade journals. For the burning trials small kilns of the muffle type are employed. The Bureau of Industrial Chemistry employs a large "Keramic Kiln" made by the Denver Fire Clay Company of Denver, Colorado, and a smaller kiln manufactured by John Lovhet of Trenton, New Jersey. For firing tests of fire clays a "Surface combustion" furnace is employed.

The chemical analyses of clays are made by standard chemical methods. These methods are described by the American Ceramic Society in connection with the methods of making ceramic tests, and they can also be found in the chemical literature. These analyses should not be attempted except by men who are thoroughly familiar with such work, as failure to understand the conditions involved may cause serious errors in results.

INDEX

TABLE I

CERAMIC TESTS FROM BULLETIN No. 102

Sample No.	Water of Plasticity	Air Shrinkage	Average Tensile Strength	Plasticity	Slaking	Texture	Cone 05		Cone 03		Cone 1		Cone 3		Cone 5		Cone 9		Cone 14		Vis. at Cone
							Shrinkage	Absorbtion	Shrinkage	Absorbtion	Shrinkage	Absorbtion	Shrinkage	Absorbtion	Shrinkage	Absorbtion	Shrinkage	Absorbtion	Shrinkage	Absorbtion	
801	25.3	6.2	253	Fa	Fst	C	—4.7		0.0	24.7	1.0	23.5	1.0	20.2	7.0	5.9					7
802	24.2	10.1	167	G	Sl		3.0	4.7													
803	23.1	9.6	202	G	Sl		5.0	2.0	6.0	0.0											
804	23.1	8.0	301	Fa	VSl		4.3	8.2	5.3	7.0	5.0	6.5	5.6	7.2	5.6	5.8	6.0	4.2			14
805	23.1	9.1	258	H	Sl		4.0	8.8	5.4	7.0	6.0	6.7	6.0	7.0	6.2	6.6					
806	17.6	4.7	149	L	Fst	C	—1.0	19.3	.3	18.6	4.3	8.3	5.6	3.7							7
807	30.8	10.2	257	H	Sl	F	1.6	11.4	2.7	9.5	3.3	6.6	5.6	2.3	5.7	2.8	9.4	0.8			28
808	20.9	6.8	245	G	Sl	F	1.7	10.7	1.3	11.3	3.4	8.7	4.0	6.3	4.3	6.3	4.4	2.3	4.0	0.0	27
809	18.7	6.7	366	L	Fst	C	0.0	24.3	1.3	24.0	1.3	24.2	1.7	20.0	—0.3	21.4					7
810	28.6	6.9	191	G	Sl		4.0	10.5	5.0	8.7	6.7	5.5	6.7	5.3	8.0	0.8					9
811	29.7	9.3	169	H	Sl		3.3	10.6	3.3	10.7	3.3	4.1	5.7	2.1							5
813	17.6	6.0	301	L	Fst	C	—1.3		0.0		—1.0		2.3		3.4						
814	19.8	6.7	291	Fa	Sl		1.0	11.3	1.0	9.9	1.7	8.4	1.3	9.1	2.0	6.0	2.1	4.2			27
815	23.1	7.6	161	Fa	Fst		0.3	14.5	0.3	14.3	0.6	13.8	0.6	13.7	1.4	11.2	3.4	4.1			14
816	19.8	8.3	357	Fa	Fst	M	1.0	23.1	1.3	22.7	0.3	22.1	0.3	21.7	1.6	14.1					7
817	19.8	6.5	266	G	Sl	C	0.7	26.5	0.0	26.3	0.0	25.5	1.7	24.5	0.7	22.4					7
818	29.7	9.6	20	L	Sl	C	1.4	16.0	2.0	15.0	1.3	14.6	1.6	13.8	5.7	4.6					9
820	35.2	10.6	15	L	Sl	F	6.4	13.7	7.7	12.2	6.7	13.4	7.0	12.1	7.0	12.9	8.3	8.6	*12.0	1.8	
821	18.7	4.8	188	L	Fst	C	0.3	14.8	0.0	15.3	0.3	14.4	0.6	14.2	0.3	15.6	0.0				
823	19.8	8.6	275	L	Fst	C	0.3	10.0	0.0	10.1	0.3	9.9	0.3	9.3	0.7	8.2					9
824	24.2	10.0	159	H	Sl		.7	15.3	1.3			8.8									3
825	16.5	6.2	224	L	Fst	C	.6	10.1	.6	9.2	.6	9.4	.6	9.5	.7	9.2	0.0		1.2	8.9	
826	23.1	9.3	316	H	Fst		.4	6.6	.7	4.5	.8	4.4	vitr								5
827	29.7	11.6	189	H	Sl		2.7	6.1			*7.3	*7.5	*7.3	*7.3	*7.7	*4.2	*8.0	*2.5			14*
829	28.6	9.1	302	G	Sl		2.0	10.3	3.0	8.3	4.3	5.7	4.3	5.7	4.6	4.6	5.4	3.8	6.0	0.2	27
830	33.0	9.3	304	H	Fst		1.0	12.1	1.0	11.2	2.7	7.9	2.7	6.6	3.5	3.1					11
831	*		L	L	Sl	F											†8.0	9.4	13.3	0.6	
832	48.4	9.4			Sl	C	11.7	19.7	11.6	20.4	13.6	14.7	14	13.2	14.6	11.6	17.3	7.0			27
833	44.0	6.9	159	VL	Sl		5	32.8	6	29.9	10	20.5	13.3	13.5	13.7	10.7	14.7	8.6			35
834	23.1	9.4	403	G	Sl		.3	10.5	.3	9.6	.3	9.4	.4	8.6	.4	7.3					9
835	33.0	12.4	487	H	Sl					6.9		5.4									
836	33.0	10.8	211	H	Sl	M	†8.0	5.7			8	7	8.7	5.8	vis						
837	28.0	9.0	398	H	Sl	M	5.3	17.2			†	10.1	6.7	6.0	6.7	5.1					6
838	28.6	9.0	308	H	Sl	M					†7.3	8.9	8.0	6.9	9.0	6.5					
838a	31.9	10.3	300	H	Sl	M	4.0	12.8	8.7	5.0	†			8.7	1.1						6
839	30.8	11.6	203	H	Sl	M					5.3	19.7	†6.7	12.1	vis						
840	31.8	10.6	366	H	Fst	M					†4.7	22.6									5
841	31.9	9.0	513	H	Sl	M	†9.3	9.0					10.7	4.8							5
842	27.5	8.6	173	G	Fst		3.0	7.7	4.7	3.1	5.0	.7	6.0	.4	7.0	.5	7.4	.4			
843	26.4	7.5	329	H	Fst		4	6.4	5.7	3.6	6.7	.6	7.4	0	.4	.6					9
844	18.6	8.0	318	H	Sl		3.6	4.8	5.4	1.1	5.7	.1	6.6	.2	7.0	.5	6.0	0			—27
845	23.0	8.6	320	G	Sl	C	.7	8.3	1.0	7.5	2.4	5.4	2.8	4.6	2.6	3.9	4.6	2.0		0.5	
846	22.0	6.4	181	G			2.3	6.5			4.0	4.7									3
848	25.3	7.7	333	G	Sl		5.6	3.6	5	1.3	5.3	.1	6.3	.1							5
849	24.2	6.1	99				1.6	18.1	2	17.6	3.4	14.7	3.6	14.7	6.0	9.8	7.0	8.3	6.7	5.2	30
850	20.9	6.3	140				.7	14.5	.7	14.6	1.7	13.1	1.7	12.9	3.0	11.1	4.0	.2			30
851	23.1	8.4	153	M		C		15.7	.4	15.5	1.6	13.1	1.4	14.0	3.0	14.0	4.3	6.8			30
852	18.7	6.6	114				.4	13.9		13.4	.6	12.9		13.0		12.5	.3	11.6	.7	8.8	27
853	28.6	7	90	G	Sl	M	0.0	19.1	.7	18.7	4.0	12.5	4.0	12.3	6.0	8.7	10.4	1.5		1.8	28
854	26.4	6.8	143	G	Sl	C	.3	16.6	1.0	16.2	4.0	13.8	4.3	12.6	6.4	11.2	6.0	7.5			30
855	25.3	9.6	302	H	Sl	M	.0	10.4	1.0	8.6	2.6	5.7	3.0	5.3	4.0	3.3	5.7	4.0			14
856	28.6	10.3	281	G	Sl		.3	14.6	1.6	12.7	2.3	9.3	3.0	6.3	6.3	5.0	5.0	2.2			27
857	26.4	9.6	207	L	Fst	C	.4	13.4	1	13.2	1.7	10.8	1.7	10.7	2	9.5	4	4.7			14
858	26.4	6.6	140	G	Fst	F	.6	15.4	1.0	15.3	2.0	13.1	3.0	11.1	4.3	8.3	6.7	2.4			27
860	37.4	11.6	154	G							6.7	5.9									9
861	19.8	5.1	83				.6	16.0	.7	16.1	.6	15.4	3.0	12.2	3.0	11.9	3.4	10.5			31
863	23.1	7.6	65	Fa	Sl		.4	20.3	.3	21.6	1.0	16.6	1.6	9.3	1.7	6.3	2.0	3.0	‡2.3	‡2.8	
865	27.6	6	315	L	Fst	C	0.0	10.7	0.0	11.1	0.0	10.0	0.0	9.8	0.0	10.8	.6	7.9	2.0	2.0	
866	23.1	6.6	200	L	Sl	M	.7	12.0	.3	12.4	0	12.6	.6	11.9	.3	11.3	1.4	8.9			
869	34.1	9.3	315	H	Fst		1.4	15.0	2.7	12.3	5.4	5.5	7.1	.1							
870	23.1	4.3	69				.4	16.6	1.3	14	2.4	13.4	2.6	11.8	2.6	12.4	4.3	8.3	5.7	4.1	31
871	20.6	5.8	128	H	Sl		4.7	4.7	7.7	.8	¶										
872a	34.1	7.2	163	Fa	Sl	C	2.7	14.5	5.7	9.6	7	6.1	8.4	3.8	8.9	.2	4.6		3.3		27
872b	26.4	6.4	139	Fa	Fst	M	0.0	16.3	1.3	14.3	2.6	11.0	2.7	12.1	4.4	8.4	7.0	2.4	6.6	2.6	27
873	35.9	12.8	356	H	Sl	F			5.3	11.1	9.3	2.6	vis								
874	26.4	5.1	66	H	Fa	C	.4	16.8	1.7	14.2	2.7	12.1	2.7	13.4	4.3	9.1	4.7	2.3	4.7	2.4	29
874a	25.3	5.8	175	G	M	M	.7	13.6	2.7	11.4	3.3	9.0	3.4	7.7	7.4	2.4	6.4	1.1	vis		
875	33	10.3		G	Fst	M	6.7	11.9			†6.7	11.7	7.6	9.5	8.4	6.4					6
876	23	8	269	H	Sl	F					†6	4.6	6	4.5	7.6	1.1					
877	30.3	10.1	302	H	Sl	M	1	12.6	1.3	11.0											1
878	24.7	6.2	188	H	Fst		2.7	10.9	†5.6	5.6	8	.1	7.7	.1	6.7						9
879	23.4	7.3	200	G	Sl		3	8.3	5	4.1	6	1.5	6	.5							
880	28.6	6.1	197	G	Sl		7.7	4.5	7.6	2.0			9.7	.1							9
881	30.0	8.1	248	H	Sl	M	2.6	12.4			4.3	9.3	5.3	8.0	6.7	4.2	8.0	2.3			
901	23.1	0.0	119	L	Fst	C	—.6	21.6	—.1	21.7	0.0	16.5	3.6	16.5	8.3	2.0					9
902	27.5	10.0	330	H	Fst	C		12.0	5	10.7											1
903	22.0	6.6	308	L	Fst	C	—.7	16.8	0.0	15.3											1
904	25.4	4.0	77	L	Fst	C	.3	9.1	0.0	9.2	0.0	9.4	0.0	9.0	.7	9.5	1.3	8.4	2.6	7.4	
905	29.7	10.3	177	H	Sl	C	.6	15.0	3	10.6	3.7	10.5	4	9.2	4	8.8	4	6.4	vis		
906	32.4	10.5	207	H	Sl	M	.7	14.6	3	11.2	3	8.8	4.3	6.2	5.1	2.1	3.7	3.6	vis		
907	20.9	3.3	122	L	Fst	C	.3	13.7	.6	13.3	0.0	13.0	0.0	12.8	0.0	12.6	00.0	11.6	¶	13.5	
908	20.9	4.6	269	L	Fst		1.0	9.3	.7	9.4	0.0	8.3	.7	8.2			2	2.7			12
909	22.0	3.4	234	L	Fst	C	.4	11.2	.4	11.2	.3	11.0	.3	10.0	0.0	9.1					9
910	27.5	8.3	259	Fa	Fst	M	—.4	19.6	—.1	17.0											1
911	28.6	4.5	153	Fa	Fst	F	—1.0	54.5	—1.0	54.0	—1.0	48.6	2.0	43.1	12.3	11.6					+9
913	18.7	7	202	H	Sl	M	1	10.8	1.6	8.7	1.7	7.5	3.0	6.1	3.0	6.4	3.0	4.6	1.3	3.0	
914	36.3	12.5		H	Sl	F			4.7	13.8	6	14.2	†		8	8.5					6
915	40.7	12.0		H	Sl	M	4.0	16.3			†8.0	7.4									6
918	19.8	6.6	340	F	Fst	M	0	21.9	0	21.3	0	21.1	1.3	17.3	.3	18.3					
919	14.3	2.0	172	L	Fst	C	—1.3	13.7	—.3	12.7	0	11.3			.3	11.4					
920	26.4	10.3	262	H	Sl	M	0	9.7	.7	9.9	.7	9.9	0	9.0	.6	9.3	vis				
921	39.6	13.0		H	Sl	M	2.7	12.3			†4	12.5									3
922	19.8	4.0	128	L	Fst	M	0	13.6	.3	13.6	.7	13.6	1.3	13.6	.3	14.0	.3	14.7			
923	30.8	5.6	47	L	Sl		2	21.7	3.0	19.2	5.0	13.8	7.0	11.3	8.3	10.1	9.3	8.6	11.6	1.5	33
925	22.0	5.8	183	H	Fst	M	2.0	11.2	1.6	13.0	3.0	9.5	4.0	7.8	4.7	4.3	4.7	3.7	3.0	2.5	
926	24.2	6.0	130				.6	15.8	.7	15.6	1.3	13.8	1.7	13.5	2.0	13.9	3.0	11.1	5.0	7.8	27
927	29.7	7.0	148	G	Sl	M	1.7	15.5	2.6	12.6	4.3	11.2	4.7	9.8	6.0	5.4	6.0	4.8	6.6	3.1	27
928	23.1	6.6	224	H	Sl	M	0.0	13.4	.7	12.4	0.7	11.8	1.0	9.2	1.7	9.2	2.0	6.5	2.7	2.7	27
929	18.7	6	90	H	Sl	F	2.3	18.7	2.4	18.2	4.0	12.2	5.0	10.4	5.0	9.2	6.3	6.3	7.3	2.3	27
930	26.4	7.3	196	H	Sl		5.3	7.3	8.0	2.4	8.0										
932	23.1	5.3	174	H	Sl	F	.3	19.7	.7	17.0											1
933	28.6	7.3		H	Fst	F	8.0	4.0	9.7	1.9											1
937	19.8	5.6	134	L	Fst	C	0	12.8	.3	12.5	.3	12.3	0	12.7	.4	12.4	.1	12.7			
943	26.4	8.6	296	H							6.7	5.9									9
944	20.9	6.6	208				2.0	11.5	3.0	7.8	3.7	6.5	4.3	4.4	5.4	4.2					
945	26.4	10.6	225	H	Fst	M	*5.3	*16.9	*6.7	*16.8			*7.3	*16.8							5
946	18.7	5.3	182	L			0.7	15.8	0.7	14.7	5.0	2.8									3
947	21.3	6.0	205	L	Sl	C	—.3	15.0	.3	13.3	7.4										3
948	24.2	7.3	204	H	Sl	M	1.3	11.8	2.3	9.5	3.3	7.8			4.6	3.6	10.7	2.1			27
949	19.8	8.0	340	H	Fst		.7	18.3	.3	16.6	1.0	13.2									3
950	36.3	1.3	61	L	Fst	C	11.3	13.7	16.0	7.9	16.0	vitr									3
951	39.6	4.0	116	L	Sl		12.7	7.7	16.6	2.0	15.3	vitr									3
952	19.8	4.0	48				.1	13.9	.7	13.5	.3	13.1	.3	12.8		12.9		12.1		11.2	33
953	24.2	6.3	217	H	Sl	F	2.0	12.5	2.0	12.4	4.0	9.3	4.6	6.7	5.0	5.5	6.6	1.4			28
954	19.8	4.0	64				.7	17.2	.4	17.2	.6	16.0	1.4	15.8	2.0	13.8	3.0	11.9	3.0	10.7	30
955	17.6	3.3	40					14.7		14.7	.1	14.6		13.1		13.1	.3	12.3			31
956	23.1	8.0	277	H	M		1.4	10.7	1.7	9.4	3.0	8.7	3.0	5.2	4.0	4.1	9.0	.2			28
957	26.4	9.0	186	H	Sl		2.3	10.5	3.0	8.9	4.7	6.4	5.0	3.1	5.3	2.6	5.7	2.2	6.6	2.7	30
958	23.1	8.0	355	H	Sl		1.6	7.7	1.6	7.2	3.0	3.6	3.6	3.9	3.7	3.0	4.0				12
959	23.1	9.6	455	H	Fst	M	.4	9.5	.7	9.1	2.3	5.8	2.3	4.5	2.6	4.7					9
960	24.2	7.6	213	H	Sl	M	1	13.1	1.7	11.7	2.7	10.9	3.4	8.9	5.3	8.4	12.7	6.5		2.2	27

*Dry Press †Steel Hard ‡Cone 12 ¶Swells and distorts

TABLE II

CHEMICAL ANALYSES FROM BULLETIN NUMBER 102

Figures marked with an asterisk (*) represent water plus organic matter

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	H_2O	CO_2	Organic Matter	Total	Total Fluxes	Cone of Fusion
801	53.6	9.0	2.6	17.8	1.2	tr.	1.8	0.8	1.0	11.6		99.4	23.4	7
802	63.0	23.0	2.5	tr.	1.1	.3	1.7	1.3	4.8			97.7	5.6	
803	63.4	23.4	1.1	.4	1.2	.3	.1	1.1	7.4*			98.5	3.2	
804	57.0	22.2	2.1	.2	tr.	.2	tr.	1.3	16.6*			99.7	2.6	
805	58.2	21.1	1.8	1.1	.1	.2	.1	1.5	14.4*			98.5	3.3	
806	59.0	11.2	2.8	12.1	.8	.2	tr.	1.0	2.1	9.6		98.9	15.9	7
807	64.9	22.7	.8	.1	.7	.7	.1	1.4	7.0			98.5	2.5	28
808	68.3	20.1	1.0	tr.	2.4	.6	tr.	1.2	6.6			100.2	4.0	27
809	37.4	7.7	2.0	27.9	.4			tr.	2.4	21.8		99.7	30.3	7
810	70.5	18.3	1.8	tr.	.9	.2	tr.	1.2	5.5			98.4	2.9	
811[1]	59.5	18.2	4.8	4.3	tr.	.2	tr.	1.1	6.2*	3.2		98.6	9.3	
813	18.6	3.2	1.3	41.3	.4			tr.	2.4	32.5		99.7	43.0	+5
814	77.0	15.9	1.3	1.1	.4			.9	4.5			101	2.7	
815	68.7	15.9	3.3	3.1	.5	.3	tr.	1.4	5.9			99.1	7.2	
816	37.1	8.1	1.8	25.3	2.2	.1	tr.	.5	2.6	22.1		99.8	29.4	7
817	41.2	6.5	2.0	24.2	1.6	.1	.1	.4	2.3	20.6		99.3	28.2	7
818	73.2	13.9	1.4	3.1	1.6	.2	tr.	.7	5.1			99.3	6.4	
820	74.8	13.6	.7	1.7	2.0	0.3	tr.	0.4	5.7			98.2	4.7	
821	80.4	9.8	2.9	.4	.5	.2	tr.	.3	3.1			97.6	3.9	
823	80.8	8.1	2.2	1.4	.3	.1	tr.	.8	6.0			99.8	5.1	
824	49.4	17.9	4.5	9.5	1.9	tr.		1.0	4.6	9.5		98.4	15.9	
825	89.0	3.7	1.6	.5	.6	.1	tr.	.8	1.6			98.0	2.8	
826	72.5	11.7	3.4	3.7	1.3	.2	tr.	.9	3.4			97.1	8.6	
827	64.0	22.6	1.2	.9	1.1	.1	tr.	1.5	5.8			97.2	3.3	
829	67.0	19.7	.7	.6	1.1	.2	tr.	1.8	6.1			97.1	2.6	
830	72.9	14.7	4.5	.6	.3	.7	1.5	1.0	4.2			99.5	7.6	
831[2]	73.0	15.8	.6	1.3	1.5	.2	.1	.4	5.8			98.7	3.7	27
832	72.5	15.0	.8	.6	.3	.3	tr.	.5	8.3			98.4	2.1	27
833	45.4	40.3	.5	tr.	tr.	.4	tr.	tr.	13.3			100.1	.9	+35
834[3]	78.0	11.0	3.2	.8	.4			1.2	3.2			98.4	4.4	
835	55.3	21.3	8.4	3.9	.3	tr.		1.0	4.3	3.3	1.4	99.1	12.5	
836	58.7	21.7	5.5	1.1	1.2	.2	.3	1.1	5.9	.3	3.0	99.1	8.3	
837[4]	55.1	23.8	3.5	3.3	1.2	.2	.5	1.0	6.0	1.7		99.8	8.7	
838	53.8	23.2	3.6	1.7	1.4	2.0	1.6	1.4	6.0	.8	3.4	99.1	10.4	
839[5]	49.6	16.1	5.6	10.1	2.1	.8	1.4	.7	5.0	6.9		99.4	19.9	
840[6]	47.9	14.4	3.6	12.3	1.1	1.5	1.2	1.2	4.8	9.5		100.3	19.7	
841	53.2	22.8	6.5	1.7	1.7	.1	tr.	1.7	7.1	3.1	2.0	99.9	9.9	
842	57.0	25.6	3.4	1.0	0.7	.8	.9	.9	10.0			100.3	7.0	
843	51.5	17.6	16.6	1.0	1.1	tr.	1.5	1.6	7.7			98.6	20.2	
844	56.2	23.7	1.5	.6	1.5	2.2	1.4	1.6	11.1			99.8	7.2	
845	69.6	15.7	2.4	2.4	2.0	.9	.8	1.2	5.0			99.8	8.3	
846	68.7	15.8	4.1	.6	1.6	.1	tr.	.6	4.1		2.1	97.7	6.4	
848	63.1	19.4	4.7	1.3	.5	0.0	0.0	1.5	6.9			99.1	6.6	
849	62.1	25.1	.3	.3	.2	.1	tr.	2.1	10.0			100.3	.9	30
850	69.9	20.5	.2	.5	.3	.3	.1	1.4	6.7			99.9	1.5	30
851	74.0	15.1	.5	.5	.3	1.1	.4	1.3	6.0			99.3	2.8	30
852	77.3	15.3	1.6	.3	tr.	.1	tr.	1.2	4.7			100.5	2.0	27
853	72.2	17.9	.4	.1	.6	.3	tr.	1.5	6.3*			99.4	1.5	28
854	70.0	17.8	.1	tr.	.2	1.1	.7	1.4	6.4			99.0	2.1	30
855	75.3	14.7	1.1	.1	1.6	.1	.6	1.3	4.5			99.3	3.5	14
856	82.4	10.9	1.1	.2	1.0			1.0	2.5			99.1	2.3	
857	72.8	14.5	3.8	.1	1.9	tr.	tr.	1.4	4.6			99.1	5.8	
858	72.1	18.0	.6	tr.	2.0	.3	.9	.7	5.8			99.5	3.8	27
860	66.0	18.8	6.3	.5	1.9	.1	0.2	0.9	4.8			99.6	9.0	
861	73.7	17.0	.5	.1	1.4	.1	tr.	1.6	6.0			100.3	2.1	31
863	79.0	11.4	2.4	.5	.2	.6	.4	.8	3.8			99.0	4.1	
865	85.3	6.7	1.9	.4	.2	.2	tr.	1.0	3.2			99.0	2.7	
866	85.6	6.7	1.4	tr.	.4	.6	.5	1.0	3.1			99.4	3.00	
869[7]	69.4	14.7	4.5	.3	1.7	2.1	1.5	1.1	4.6*			99.9	10.1	
870	74.0	17.1	.6	.1	.2	.6	.3	1.4	6.1			100.4	1.8	31
871	58.5	18.2	7.5	1.2	3.8	2.9	1.1	1.0	5.5			99.0	16.6	
872[8]	72.0	17.6	.8	tr.	.2	tr.	1.2	1.4	5.6			98.8	2.2	27
872[9]	63.3	23.4	1.6	tr.	.3	1.0	.9	1.2	7.6			99.3	3.8	26
873	51.3	14.4	6.2	10.3	tr.	4.1	tr.	.8	4.9	7.6		99.6	20.6	3
874	71.6	17.1	1.6	.1	.9	.9	.4	1.3	5.8			99.7	4.0	29
874[a]	72.0	16.4	.6	.5	1.4	.8	tr.	1.0	6.1			98.8	3.3	14
875[b]	59.3	15.7	5.8	3.0	2.1	1.4	.6	1.8	7.0	1.1	2.	100.1	12.8	
876	54.5	22.6	6.2	.5	1.1	1.6	1.4	1.2	6.7		3.4	99.9	10.8	
877	51.9	12.4	4.6	12.5	1.4	2.4	1.5	.7	8.5	5.5		101.4	22.4	3
878	60.5	19.4	9.3	tr.	.3	1.5	1.4	.6	6.5		2.8	99.5	12.5	
880	63.3	24.5	1.3	.1	.2	1.3	2.3	1.0	6.1		2.6	100.1	5.2	
881	70.0	18.6	4.5	tr.	tr.	.9	tr.	.6	6.1			100.7	5.4	
901	65.9	10.6	1.9	9.3	1.2			.9	2.6	7.7		100.2	12.5	9
902	63.6	8.2	4.3	10.0	.1	1.0	tr.	1.0	4.2	7.4		99.7	15.5	1
903	65.1	9.2	2.8	8.4	.2	1.7	.5	1.1	3.7	6.9		99.5	13.6	1
904	90.0	4.6	1.4	.1	.1	tr.	tr.	.7	3.0			100.0	2.3	
905	73.1	9.9	6.9	1.5	.2	.1	tr.	1.0	6.6			99.4	8.8	
906	68.5	18.4	3.0	.7	1.1	.9	.5	1.3	6.2			100.6	6.1	
907	83.9	5.5	4.7	.4	1.3	.5	.2	1.6	2.4			100.5	7.1	
908	83.5	8.5	1.4	1.0	1.1	1.5	.5	1.1	2.4			100.9	5.5	
909	81.5	5.4	3.6	1.3	.2	1.6	.5	.9	4.0			99.0	7.2	
910	51.1	11.0	4.1	14.2	.9	1.6	.4	1.0	4.0	10.6		99.0	21.3	1
911	21.7	8.0	2.2	36.5	1.0	tr.	tr.	.5	2.1	28.4		99.7	39.7	+9
913	70.0	18.7	1.2	.5	1.2	1.5	tr.	1.0	6.1			100.2	5.4	
914[c]	67.0	17.6	3.7	tr.	1.3	1.6	.7	2.1	5.2		1	100.7	7.2	
915[d]	64.2	20.1	1.9	.3	1.6	1.8	.7	2.0	5.3	tr.	1	100.7	6.3	
918	47.2	4.1	2.4	21.0	1.4	1.3	tr.	.7	2.9	18.1		99.1	26.1	
919	82.4	3.2	.7	5.3	.4	.2	.9	.2	3.3	4.0		99.7	7.6	
920	78.5	10.5	3.6	.4	.2	.4	.9	.3	4.2			99.1	5.6	
921	53.5	14.8	6.2	8.1	1.4	1.6	.8	1.0	6.9	4.7		99.0	18.2	
922	87.3	4.1	3.5	1.0	.1	.2	tr.	.5	2.4			99.1	4.8	
923	57.4	28.8	.7	.1	.1	.5	tr.	1.5	10.4			99.5	1.4	33
925	65.6	20.5	1.4	1.7	.3	.6	1.0	.3	7.5			98.9	5.1	27
926	69.7	21.5	.4	tr.	.5	1.0	.3	.1	7.1			100.6	2.3	27
927	67.8	21.8	1.0	tr.	tr.	1.1	.4	1.5	7.4			101.0	2.5	27
928	78.2	8.7	.7	3.4	1.1	1.2	.4	.2	5.5			99.4	6.8	27
929	69.8	15.8	1.6	3.4	.5	1.0	.5	.2	6.7			99.6	7.1	26
930	56.0	24.1	2.6	tr.	1.1	1.4	1.2	1.6	7.3		4	99.4	6.3	
932	51.3	18.4	4.5	tr.	7.1	1.8	1.8	1.2	4.4*	8.0		99.2	15.2	1
933	59.4	21.2	4.7	1.5	1.9	1.7	2.6	1.4	6.4*	.3		101.1	12.4	1
937	83.8	9.2	2.3	tr.	tr.	.5	.6	.9	3.1			100.4	3.4	
943	62.4	22.6	3.7	.2	.2	1.7	1.4	1.1	6.8			100.3	7.3	
944	62.3	23.8	3.0	tr.	.1	1.6	1.2	1.4	7.1*			100.4	5.9	
945	34.6	15.0	3.0	21.5	.1	1.3	1.4	1.0	6.0	15.6		99.6	27.4	5
946	72.4	7.8	1.7	6.5	2.2	1.7	1.2	.1	3.7	3.3		100.6	13.3	
947	71.4	8.2	2.3	6.3	2.4	1.6	1.2	.1	3.7	3.2		100.6	14.9	2
948	68.8	21.1	1.2	tr.	tr.	1.1	.4	1.2	6.6			100.5	2.7	27
949	38.1	11.4	2.6	23.7	tr.	1.6	.6	.7	3.1	18.8		100.4	28.5	
950	68.3	15.3	3.4	1.2	.9	3.5	2.5	.5	4.7			100.4	11.5	
951	68.6	18.5	.7	.6	.1	2.7	2.3	.4	7.0			100.9	6.4	
952	83.0	7.4	.4	tr.	3.0	1.3	.3	.7	3.7			99.7	4.9	33
953	68.6	20.5	.7	tr.	.4	.2	1.3	1.1	6.3			99.2	2.7	28
954	70.8	18.9	.4	tr.	tr.	.5	tr.	2.1	6.8			99.5	.9	31
955	77.4	15.7	.7	tr.		tr.	tr.	.7	5.7			100.2	.7	
956	71.3	19.7	1.0	2.1	tr.	.8	tr.	tr.	5.8			100.7	3.9	28
957	65.6	22.5	1.2	.7	tr.	1.7	tr.	.1	7.7			100.5	3.6	30
958	70.4	17.3	1.8	1.0	tr.	2.2	.6	.8	5.4			99.5	5.6	
959	72.7	9.5	4.1	4.1	.8	tr.	2.4	.6	4.5	.4		99.1	11.0	
960	74.3	16.0	1.4	tr.		.6	.5	.5	7.0*			100.3	2.5	27

[1] 0.9% SO_3
[2] Tr. MnO_2
[3] 0.5% SO_3
[4] 3.4% SO_3
[5] 1.1% SO_3
[6] 1.4% SO_3
[7] Tr. SO_3
[8] 0.3% SO_3
[9] 1.8% SO_3

TABLE VII

CERAMIC TESTS MADE BY SAN ANTONIO CHAMBER OF COMMERCE

The Bureau of Industrial Chemistry accepts no responsibility for the accuracy of these tests or the conclusions drawn from them as shown in this table.

Sample Number	Reported Location of Deposit	Reported Owner of Deposit	Raw Color	Plasticity	Firing test at 2000° F.			Firing test at 2200° F.			Firing test at 2350° F.			Suitable for
					Color	Linear Shrinkage Per Cent	Warpage	Color	Linear Shrinkage Per Cent	Warpage	Color	Linear Shrinkage Per Cent	Warpage	
SA 2	Pleasanton	Albert Goll	l.br	F				b.	1.5	none				Nothing—test pieces crumble
SA 3	Pleasanton	Albert Goll	y.br.	VF				b.	1.5	none				Nothing—same reason
SA 4	Pleasanton	Albert Goll	l.br.	VF				b.	1.5	none	grn.	4.7	bad	Nothing—same reason
SA 5	Pleasanton	Albert Goll	d.cr	F	l.cr.	6.2	none	wh.	6.2	none	grn.		bad	Nothing—same reason
SA 6	Natalia	C. H. Kearney	l.br.	P	r.	1.5	none	b.	1.5	none	r.br.	1.5	none	Brick or tile—grade A
SA 7	Natalia	C. H. Kearney	l.br.	P	b.	3	none	b.	3	sl.	l.br.	4.7	sl.	Brick or tile—grade A
SA 8	Natalia	C. H. Kearney	l.br.	P	b.	0	none	b.	0	none	sal.	0	none	Brick or tile—grade A
SA 9	Natalia	C. H. Kearney	y.br.	P				r.br.	1.5	sl.	d.r.	3	sl.	Brick, tile or terra cotta—grade A
SA 13	Navasota		wh.	P	r.	22	bad	choc.	16	fu.	y.br.		fu.	Slip clay—grade C
SA 14	San Antonio	B. J. Wilkinson	br.grn.	G	r.	9	none	bl.		fu.	bl.		fu.	Brick or tile—grade A
SA 16	Natalia	C. H. Kearney	br.	F	b.	6	none	b.	6	none	b.	6	none	Brick, tile, art ware—grade A
SA 17	Natalia	C. H. Kearney	gr.br.	G	l.b.	8	none	b.	10	none	b.	10	none	Brick, tile or terra cotta—grade A
SA 18	Natalia	C. H. Kearney	br.	G	pink	10	none	l.cr.	9	V sl	d.y.	12.5	sl.	Brick, tile, etc.—grade A
SA 19	Natalia	C. H. Kearney	l.y.br.	G	l.o.	8	none	r.b.	9.4	sl.	r.br.	12.5	sl.	Roofing tile, brick, etc.—grade A
SA 21	9 mi. northeast of Fowlerton	Tom Kuykendall	gr.		cr.	9.4					gr.	12.5		Kaolin—grade B
SA 22	Wilson County		d.r.br.	F	r.	12.5	none	d.r.	12.5	none				Brick or tile—grade A
SA 23	San Antonio		br.grn.	VF	r.	12.5	none	d.r.	14	sl.				Bricks—grade A
SA 24	Flatonia		wh.	VP	gr.br.	17	sl.	cr.	17	none	cr.	17	none	Kaolin—grade C
SA 25	Near Leakey		wh.	P	pink	9.4	V sl	wh.	9.4	none	wh.	17	none	White ware—grade B
SA 26	Corpus Christi		cr.	P	b.	19	sl.	cr.	17	none	cr.	22	none	Kaolin—grade C
SA 29	10 miles from Pleasanton		r.	P				d.r.	6	none				Brick—grade C
SA 30	10 miles from Pleasanton		gr.	P				r.	11	none				Brick mixture—grade C
SA 31	10 miles from Pleasanton		br.gr.	P				r.	1.5	none	d.r.	1.5	none	Brick mixture—grade C
SA 32	Medina		mixed gr.brn and br	G	tan	9.4	none	b.	11	none	br.gr.	12.5	none	Brick and tile—grade A
SA 33	Pleasanton		br.	P	r.	4.5	none	d.r.	4.5	none	r.	4.5	none	Constituent of brick mix.—grade C
SA 34	10 miles from Pleasanton		br.	P	r.	8	none	d.r.	10	sl.				Common brick—very sandy
SA 36	Atascosa County	W. J. Miller	br.	VG	b.	12.5	none	b.	12.5	sl.	d.b.	14	sl.	Brick, tile or terra cotta—grade A
SA 40	Gonzales	Judee Harwood	wh.	VP	gr.	20	none	wh.	20	none	wh.	20	none	Kaolin—grade B
SA 47	San Antonio	N. P. Fike	gr.br.	VG	l.r.	8	V sl			fu.				Brick and tile—grade A
SA 48	Pleasanton		d.br.	P	d.r.	8	none	d.r.	8	none				Constituent of brick mix.—grade C
SA 49	Pleasanton	H. Krause	gr.	P	lbr.	4.7	none	br.	4.7	none				Brick—grade A
SA 51	Waelder	Nash Waelder	l.r.	VP	r.	7	none	r.	7	none				Common brick—grade C
SA 53	Victoria	Central Power and Light Co.	d.r.br.	P	r.	6	sl.							Constituent of brick mix.—grade C
SA 54	Victoria	Central Power and Light Co.	bl.	F	br.gr.	12.5	V sl	r.	5.5	V sl.				Common brick—grade C
SA 55	Pleasanton	Walter Epple	grn.br	G	l.grn.	2	none							Nothing—test pieces crumble
SA 56	Pleasanton	H. Krause	l.	VG	r.and blue	17	bad							Nothing—warps and cracks
SA 57	Pleasanton	H. Krause	grn.	VG	l.r.	9.5	bad							Bricks—grade A
SA 58	Flatonia		br.gr.	VP	gr.b.	7.8	bad							Constituent of brick mix.—grade C
SA 59	Flatonia		l.gr.	VP	gr.p.	20	sl.	gr.p.	20	sl.				Nothing
SA 60	Flatonia		wh.	VP	l.br.	22	some	l.br.	22	sl.				Kaolin—grade C
SA 61	Flatonia	Albert Goll	br.and blue	G	r.	7.8	none							Brick—grade A
SA 62	Waelder		gr.	G	b.	7.8	none	b.	9.4	sl.				Brick or tile—grade A
SA 64	Pleasanton	Walter Epple	d.br.	VF	l.r.	6	some							Nothing—cracks badly
SA 65	Pleasanton	Walter Epple	l.br.	F	grn.	4.7	none							Nothing—test pieces crumble
SA 67	Three Rivers		wh.	P	r.tan	17	none	r.	17	none	slate	19	none	Kaolin—grade C
SA 69	Kelly Field road, San Antonio		grn.br.	F	r.	7.8	none							Common brick—grade C
SA 72	San Antonio	R. V. Sauer	d.br.	VG	r.	7.8	bad							Nothing—cracks badly
SA 73	Washington Co.		wh.	P	tan	12.5	sl.	d.br.	12.5	sl.	gr.br.		bad	Kaolin—grade C
SA 74	Grimes Co.		wh.	G	tan	22	none	choc.	22	none	choc.		fu.	Kaolin—grade C
SA 80	Victoria		d.br.	VG	b.	8.6	none	grn.	8.6	none				Bricks—grade B
SA 86	Calaveras	Theo Johns	d.br.	G	b.	9.5	none	b.	12.5	bad				Brick—grade C
SA 87	Calaveras	Theo Johns	l. br.	F	b.	3	none	b.	3	sl.				Nothing—test pieces crack
SA 88	Calaveras	Theo Johns	d.br.	F	b.	6	none	b.		bad				Brick—grade C
SA 89	Coughran	J. A. Warburton	blue and br.	G	r.	11	bad							Constituent of brick mix.—grade C
SA 90	Bexar County	F. P. Carle	gr.		gr.	1.5	none	grn.		none				Nothing—test pieces crumble
SA 97	2½ miles northeast of Yorktown	Henry Jablonski	r.br.	F	r.	12.5	sl.							Constituent of brick mix.—grade C
SA 99	San Antonio	Mrs. Mary Schuh	y.	G	grn.br.	3	sl.	grn.br.	10	bad				Nothing—test pieces crack
SA100	San Antonio	Mrs. Mary Schuh	y.	G	r.	8.5	sl.			fu.				Brick and tile—grade C
SA101	San Antonio	Mrs. Mary Schuh	br.	G	r.	8.5	bad			fu.				Brick and tile—grade B
SA102	San Antonio	Mrs. Mary Schuh	bl.	F	br.	10	bad							Nothing—cracks badly
SA103	San Antonio	Mrs. Mary Schuh	y.	G	grn.	5.5	sl.	grn.	10	bad				Nothing—cracks badly
SA104	Prairie Lea		pink	VP	purple	15.5	none	wh.	22.5	none	gr.slate	22.5	none	Kaolin—grade B
SA105	Prairie Lea		pink	VP	slate	11	none	l.br.	22	bad				Kaolin—grade C
SA110	Adkins	Guy Edwards	grn.br.	G	l.gr.	6	sl.	l.cr.	8	sl.				Brick and tile—grade A
SA111	Adkins	Guy Edwards	grn.br.	G	l.gr.	6	none	b.	7	sl.				Brick or tile—grade A
SA112	Adkins	Cantu heirs	gr.	G	wh.	6	none							Possible refractory—grade A
SA114	Gonzales	L. D. DuBose	gr.	F	gr.		none	grn.	10	sl.				Kaolin—grade C
SA115	Dunley	E. E. Lehmberg	br.	F	y.br.			br.						Nothing—cracks on firing
SA116	18 miles west of Junction	O. J. Camp	grn.	G	b.	9.5	sl.	b.	9.5	sl.				Brick—grade C
SA117	8 miles from San Antonio	George Zumbeal	d.br.	G	d.r.			d.r.						Nothing—cracks on firing
SA118	San Antonio	Charles Schuh	br.	G	r	11	bad							Nothing—test pieces crumble
SA119	San Marcos	W. C. Johnson	y.	G	grn.	14	bad							Brick—grade C
SA120	5 miles south of San Marcos	W. C. Johnson	br.	F	grn.	8	sl.	grn.		bad				Nothing—too much lime
SA121	Corpus Christi	John Dunn	d.br.	G	l.r.	8	sl.			fu.				Nothing—test pieces crumble
SA122	Corpus Christi	John Dunn	br.	G	grn.r.	11	sl.							Nothing—cracks and checks
SA123	Corpus Christi	John Dunn	br.	G	r.grn.	12.5	sl.							Nothing—cracks and checks
SA124	6 miles north of Whitsett	C. C. Klumpp	d.grn.	G	b.	9.5	none	d.r.	9.5	none	d.br.	12.5	none	Constituent of brick mix.—grade C
SA126	Adkins	Mrs. T. E. Trainer	gr.	VP	gr.	0	none	br.gr.	0	none	br.gr.	0	none	Very sandy—grade C
SA127	New Braunfels	R. Warnecke	wh.	G	grn.	10	sl.							Nothing—test pieces crumble
SA128	4 miles north of Pearsall	R. O. Willman	r.	F	d.br.	8	V sl	d.r.	8	V sl				Constituent of brick mix.—grade C
SA129	3 miles south of Moore	R. O. Willman	wh.	F	grn.	2	sl.							Nothing—test pieces crumble
SA130	7 miles north of San Marcos	C. C. Clark	d.br.	G	grn.	4	sl.							Nothing—test pieces crumble
SA131	13 miles west of Crystal City	Hiser Estate	l.br.	P	r. br.	2.5	sl.							Constituent of brick mix.—grade B
SA132	6 miles north of Whitsett	C. C. Klumpp	br.gr.	G	r. br.	8	none				br.			Constituent of brick mix.—grade C
SA133	2 miles west of Elmendorf	J. M. Smith	gr.	F	l.br.	4	none							Constituent of brick mix.—grade C
SA134	San Antonio	J. C. Houston	br.	VP	r.br.	6	none							Constituent of brick mix.—grade C
SA145	8 miles east of Rio Grande City	F. G. Tappon	pink	G	br.	6	none			fu.				Nothing
SA146	10 miles southeast of Menard	B. M. Westbrook	gr.	G	gr.	6	none	grn. b.	6	none	l.grn.	12	bad	Brick or tile—grade A
SA147	4 miles west of Stockdale	W. M. Edmondson	br.	P	d.br.	4.5	sl.							Nothing—test pieces crack
SA149	Von Ormy	W. J. Miller	r.	F	r.	6	sl.	r.		none				Possibly refractory
SA151	Kyote	J. C. Peterson	grn.gr	G	b.	7	bad							Nothing—checks and cracks
SA152	Sabinal	Mrs. Ed. Meyers			b.	0	none							Nothing—too much lime
SA154	Barksdale	J. A. Blalack	d.br.	G		-2.5								Nothing—cracks badly
SA155	Whitsett	Farmers Life Ins. Co.	cr.	G	blue gr.	19	none	grn. br.	26	sl.				Nothing
SA157	12 miles southeast of San Antonio	Frank Weber	br. and gr.	F	gr.	4.5	sl.	br.b.	6	sl.	d.	8	sl.	Face brick, etc.—grade A
SA158	6 miles northwest of Gonzales	W. D. Staton	cr.	P	b.	0	none	b.	4.5	bad				Nothing—test pieces crumble
SA159	Gonzales	W. D. Staton	br.	G	B.	15.5	none	v.d.br.	15.5	none				Brick or tile—grade A
SA160	Gonzales	Sunset Brick and Tile Co.	br.	G	b.	6	sl.	b.	6	bad	b.	6	bad	Nothing
SA161	Gonzales	Sunset Brick and Tile Co.	br.	G	r.	8.6	bad	b.						Nothing
SA162	San Antonio	Charles Schuh	grn.br.	G	r.	8	bad							Nothing—test pieces crack
SA163	San Antonio	Charles Schuh	grn.br.	G	d.r.	12.5	sl.							Nothing—test pieces crack
SA164	5½ miles west of Raymondville	Frank G. Hawkes	bl.	G	br.	14	bad							Nothing—test pieces crack

TABLE VII (CONTINUED)

CERAMIC TESTS MADE BY SAN ANTONIO CHAMBER OF COMMERCE

Sample Number	Reported Location of Deposit	Reported Owner of Deposit	Raw Color	Plasticity	Firing test at 2000° F.			Firing test at 2200° F.			Firing test at 2350° F.			Suitable for
					Color	Per Cent Linear Shrinkage	Warpage	Color	Per Cent Linear Shrinkage	Warpage	Color	Per Cent Linear Shrinkage	Warpage	
SA170	Pleasanton	J. R. Martin	gr.br.	G	salmon	4	none	salmon						Brick or tile—grade A
SA171	Pleasanton	J. R. Martin	l.br.	G	r.br.	12.5	much	choc.		none				Brick or tile—grade A
SA173	San Antonio	W. P. Fike	br.and blue	G	grn.	7	bad							Common brick—grade C
SA175	Atascosa Co.	C. L. Witherspoon						cr.						Possibly kaolin—grade B
SA176	2½ miles west of Elmendorf	Charles Foerster	br.	G	pink	8	sl.	grn.		fu.				Brick or tile—grade B
SA177	Elmendorf	Charles Foerster	l.br.	VP	br.b.	0.8	sl.	b.	0.8	sl.				Nothing—test pieces crumble
SA178	6 miles south of New Braunfels	E. Doppenschmidt	grn.br.	F	b.	9.5	V sl	br.and y.						Nothing
SA179	6 miles west of New Braunfels	E. Doppenschmidt	grn.br.	F	b.	9.5	V sl	br.and y.						Constituent of brick mix.—grade C
SA181	3 miles west of D'Hanis		slate	G	l.r.	12.5	none	blue grn.		fu.				Brick or tile—grade A
SA184	Von Ormy	W. J. Miller	br. and r.	G	b.	8	none	d.r.br.	11	sl.	br.	11	sl.	Brick or tile—grade A
SA186	14 miles west of San Antonio	L. J. Jarmon	br.	F	br.	12.5	bad							Nothing—too much lime
SA190	Birdville		l.br.	G	choc.	12.5	none	l.r.			d.r.			Brick or tile—grade A
SA193	San Antonio		gr.	G	grn. br.	11	bad	bl.		fu.				Constituent of brick mix.—grade C
SA194	5 miles from Westhoff	Alois W. Klecka	br.and blue	F	b.	9.5	sl.							Nothing
SA195	1 mile northeast of Uvalde	J. W. Vanham	l.br.	G	l.r.	8	sl.	br.		vit.				Common brick—grade C
SA196	Moulton		l.br.	VP	grn.b.	3	none	gr.	9.5	none, fu				Nothing
SA198	1 mile northwest of D'Hanis	Mrs.FloraWallrath	br.	G	r.br.	11					l.br.		fu.	Brick or tile—grade A
SA199	1 mile northwest of D'Hanis	Mrs.FloraWallrath	slate	G	b.	8	none	grn.b.	9.5	sl.				Brick or tile—grade A
SA201	8 miles west of San Antonio	B. F. Schmidt	l.br.	G	l.br.	8.5	none							Brick or tile—grade A
SA202	25 miles west of San Antonio	Walter Grosser	wh. and br.	VP	grn.	–3.0	bad							Nothing—test pieces crumble
SA203	Annarose	Mrs. R. Schaffer	l.r.	F	salmon	4.5	sl.				gr.		fu.	Nothing—too much lime
SA204	Annarose	Mrs. R. Schaffer	br.r.	P	r.br.	5.5	sl.	d.br.	8	sl.				Constituent of brick mix.—grade B
SA205	Annarose	Mrs. R. Schaffer	gr.	G	l.br.	6	none	gr.	9	none				Bricks—grade A
SA206	14 miles northwest of San Antonio	L. J. Jarmon	l.br.	G	r.br.	17	bad							Nothing
SA208	14 miles northwest of San Antonio	L. J. Jarmon	l.br.	F	tan	19	none							Bricks—grade B
SA211	1½ miles east of Leming		gr.br.	VP	tan	0.8	none	tan	2.5	none				Brick or tile—grade A
SA212	McMullen Co.	T. R. Kuykendall	wh.	F	b.	19	none	l.b.	19	none				Kaolin—grade A
SA214	4 miles west of Rio Frio	J. B. Owings	l.br.	F	grn.	–4.7								Nothing—too much lime
SA216	San Antonio	W. P. Fike	l.br.	F	d.b.	7	sl.	br.b.						Nothing—too much lime
SA219	San Antonio	W. P. Fike	l.br.	G	l.r.	8	sl							Brick or tile—grade A
SA222	15 miles east of San Antonio	Cantu heirs	gr.	P	wh.	3	none				gr.	3	none	Probably refractory
SA223	Campbellton	A. R. Ponder	grn.gr.	G	l.br.	8	none				l.br.		fu.	Bricks—Grade A
SA225	Leakey		wh.	F	wh.	11	none				wh.	4.5	none	Kaolin—grade A
SA230	Birdville		blue	VF	choc.	12.5	none							Brick or tile—grade A
SA231	Leakey		d.r.br.	G	V d.br.	11	none							Kaolin—grade A
SA234	Leakey		d.br.	G	gr.	8	none	d.gr.	8	none	b.	6	none	Kaolin—grade A
SA235	Leakey		gr.	F	gr.	4.5	none	gr.	4.5	none	l.b.	8	none	Kaolin—grade A
SA236	Leakey		gr.	G	gr.	4.5	none	gr.	6	none	l.b.	7	none	Kaolin—grade A
SA237	Three Rivers		d.gr.	G	tan	11	none	grn.b.		sl.	grn.		bad	Brick or tile—grade A
SA239	1½ miles north of St. Hedwig		r.	G	l.r.	15.5	none							Brick, tile or pottery—grade A
SA240	Atascosa Co.		y.	F	l.r.			r.	15	none				Brick, pottery, etc.—grade A
SA241	Atascosa Co.		gr.	F	grn.	4								Nothing—test pieces crumble
SA242	7 miles south of Kerrville	Mr. Spicer	cr.	P	l.grn.	0	none							Nothing—test pieces crumble
SA243	D'Hanis	F. J. Carle	gr.	P	d.gr.	–0.8	none				gr.	0	none	Possible refractory
SA244	D'Hanis	F. J. Carle	l.br.	G	b.	8.5	none	d.b.	9.5	none	drab	12	sl.	Bricks, etc.—grade A
SA247	Victoria	D.H.Braman heirs	r. and br.	G	r.br.	7	sl.							Bricks, Etc.—grade A
SA248	Victoria	D.H.Braman heirs	gr.br.	F	r.br.	7	sl.	d.r.br.	8	sl.				Bricks, etc.—grade B
SA249	Victoria	D.H.Braman heirs	br.	G	r.br.	7	sl.							Nothing—too much lime
SA250	Victoria	D.H.Braman heirs	br.	F	r.br.	6	sl.							Bricks, etc.—grade A
SA251	2½ miles east of Stockdale	Mrs. P. Cushing	br.r.	P	r.br.	4	sl.							Constituent of brick mix.—grade B
SA252	2½ miles east of Stockdale	Mrs. P. Cushing	r.br.	F	d.br.	11	sl.							Bricks, etc.—grade A
SA253	3½ miles west of Moulton	Wm. Ohl	gr.grn.	F	br.b.	11	none							Nothing—test pieces crumble
SA254	Dilworth	Fred J. Boening	br.	G	l.r.	11	sl.	br.	11	sl.	r.br.	11.5	none	Bricks, etc.—grade A
SA255	McMullen Co.	Frank Genser	gr.	P	b.	10	sl.	grn.b.	11	none	grn.b.	14	none	Bricks, etc.—grade B
SA262	Victoria	A. Bect Estate	l.br.	G	br.	11	none							Constituent of brick mix.—grade C
SA263	60 miles west of San Antonio	Mr. Maddock	wh.		wh.						pink			"Whiting"
SA268	2 miles northeast of Fentress	John Allen	r.	G	d.r.	11.5	sl.	r.br.	12.5	none	d.r.br.	12.5	none	Brick or tile—grade A
SA271	Annarose	Mrs.S.M.Freeborn	bl.	F	l.br.									Bricks—grade A
SA285	½ mile west of Portland		br. and bl.	G	d.br.	13.5	sl.							Nothing—too much lime
SA286	½ mile west of Portland		l.br.	G	l.br.	12.5	sl.							Nothing—too much lime
SA287	½ mile west of Portland		l.br.	F	r.br.	12.5	sl.							Bricks, etc.—grade B
SA289	Whitsett		gr.	F	tan	11		cr.br.	22	none				Brick or tile—grade A
SA293	Carrizo Springs		l.br.	F	tan	3	none	l.br.	3	none	l.br.	6	vit.	Brick or tile—grade A
SA294	Carrizo Springs		d.br.	P	r.br.	0	none	r.br.	0	none	d.r.br.	3	none	Brick or tile—grade A
SA295	Carrizo Springs		grn.br. and br.	F	l.br.	6	none	d.br.	6	none	l.br.	8	none	Brick or tile—grade A
SA296A	Natalia		grn.	G	r.br.	8.5	none	br.grn.	12.5	bad				Bricks—grade A
SA297	Natalia		grn. br.	G	l.br. br.	11	none	grn.	15.5	bad				Bricks—grade A
SA299	Adkins	W. C. Nipper	br.	G	tan	11	sl.							Nothing—too much lime
SA303	Natalia		l.br.	P	l.br.	0	none	br.	–2.5	none				Constituent of brick mix.—grade C
SA321	1½ miles south of Flatonia		grn.br.	F	d.br.	13.5	sl.							Nothing—too much lime
SA323	New Braunfels	Arthur H. Dietz	l.br.	G	br.	7	none							Nothing—too much lime
SA324	College Station		l.gr.	F	b.	12.5	sl.							Bricks—grade A
SA325	Burton		wh.	F	b.	25	none				br.b.	25	bad	Constituent of brick mix.—grade C
SA327	Granger	Frank Genser	l.br.	G	l.br.	13.5	sl.							Nothing
SA330	¾ mile west of Normanna		l.br.	G	l.br.	10	none							Bricks—grade A
SA333	80 miles northwest of Marfa	Oscar Medley	gr.		gr.	0		wh.	0		gr.wh.	0		Possibly refractory
SA356	Von Ormy	V. L. Cromwell												Nothing—too much lime
SA359	Von Ormy	V. L. Cromwell	gr.	G	b.	15	sl.	br.b.	12.5	sl.	d.br.b	15	none	Brick, tile, terra cotta, etc.
SA360	Von Ormy	V. L. Cromwell	d.br	G	pink	11	sl.	br.b.	11	sl.	d.br.	15.5	none vit.	Brick, tile, or pottery—grade A
SA361	Von Ormy	V. L. Cromwell	l.br.	G	b.	10	sl.	b.	10	sl.	d.b.	13	vit.	Brick, tile, or pottery—grade A
SA366	San Antonio	J. R. Martin		F	l.r.br.	4	sl.	d.r.br.	5.5	sl.				Brick or tile—grade A
SA370	15 miles from Fredericksburg	D. A. Riley	gr.								gr.wh.			Quartz—grade A
SA380	LaGrange	J. C. Melcher	gr.		b.	6								Refractory—grade B
SA386	Von Ormy	W. J. Miller	gr. and br.	G	r.br.	12.5	none	choc.	11.5	sl.vit.				Brick or tile—grade A
SA390	22 miles south of San Antonio	Julius E. Espey	slate	G	b.	12.5	sl.	d.b.	15.5	none	d.b.	13.5	none	Brick or tile—grade A
SA391	1½ miles north of Three Rivers		cr.	P							d.b.	47	none fu.	Nothing
SA405	Atascosa Co.	Otto Brotze		G	l.b.	8.5	none	l.b.	9.5	none	b.	11	none	Brick, tile, etc.—grade A
SA416	12 miles south-east San Antonio	Frank H. Weber		G	br.b.	8	none	d.b.	8	none	br.b.	8	none	Brick or tile—grade A
SA417	Adkins	E. M. Edwards	br. and gr.	G	pink	5.5	none	b.	8	none	b.	8	none	Brick, tile, etc.—grade A
SA421	Natalia			G	l.br.	9.5	none	d.r.	11	none	blue br.	11	none vit.	Brick, tile, etc.—grade A
SA422	22 miles south of San Antonio	Julius E. Espey		F	br.b.	7	none	br.b.						Brick, tile, etc.—grade A
SA424	San Antonio	E. W. Jackson	l.br.		d.br.	9.5		d.br.	6	vit.				Bricks—grade A